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A Fifty-Year History of the Weed and Brush Program in Texas and Suggested Future Direction

Texas Agricultural Experiment Station • Edward A. Hiler, Director • The Texas A&M University System • College Station, Texas

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A Fifty-Year History of the Weed and Brush Program in Texas and Suggested Future Direction

Rodney W. Bovey*

Summary

Research on mesquite control was initiated by the Texas Agricultural Experiment Station (TAES) in the late 1930s. The U.S. Department of Agriculture (USDA) also recognized the serious nature of the weed and brush problem on Southwest rangelands and established a cooperative program with TAES by placing a scientist at Spur, Texas, in 1948. By 1953, 2,4,5-T had been developed and was being used commercially for control of honey mesquite and associated weeds and brush. At the same time, control methods were being developed by TAES for brush in addition to mesquite, including cedar, pricklypear, oaks, and mixed brush in East-Central and South Texas.

The USDA added a scientist at College Station, Texas, in 1952 to work on the basic principles of herbicide sprays, mesquite physiology, and herbicide effects on crop plants. This work was continued by other Agricultural Research Service (ARS) scientists stationed at College Station. Additional work included propagation of woody plants for experimentation; evaluation of herbicides; absorption, translocation, and metabolism of herbicides in woody plants and forages; and the anatomy and morphology of woody plants.

In the 1960s, work was expanded in Texas supported by a Department of Defense (DOD) project to investigate woody plant defoliation and control with herbicides. Six ARS scientists, including an Agricultural Engineer, contributed to work on herbicide delivery systems. The USDA-ARS scientists worked closely with TAES scientists in woody plant research. The DOD support continued about 2 years, after which ARS supported the research. The ARS scientists added basic research support to the more applied research of TAES.

During the 1960s, Texas Technological University at Lubbock received special state appropriations to intensify their brush control efforts. The TAES programs were significantly strengthened in the weed and brush control area in the 1960s and 1970s by the addition of several scientists. ARS also added new scientists at Temple, Texas, in the 1970s and 1980s to strengthen the brush ecology and biological weed control programs.

The ARS Application Technology Research Unit has provided leadership and new technology in aerial application of herbicides and pesticides. The research unit is unique in that it is the only one of its kind in the United States.

The TAES has made numerous contributions to the knowledge and practical use of range improvements and continues to do so, although funding and research efforts have

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greatly diminished. ARS no longer researches herbicides and TAES efforts are minimal. Part of this change has resulted from changes in philosophy. In the 1950s, attempts were made to eradicate or control weeds and brush. A more holistic approach to vegetation management developed in the 1980s and 1990s. New emphasis is on alternative methods to contain costs, such as prescribed burning and biological control. In addition adverse press against agricultural chemicals has contributed to this change. However, integrated weed and brush management systems will continue to utilize all methods of vegetation management appropriate for the situation.

The Texas Agricultural Extension Service has played a vital role in providing information on management of weeds and brush on rangelands and in developing programs to integrate weed and brush control methods with other management decisions.

It is the recommendation of this report that all forms of weed and brush managment research be continued, including herbicides, and with special emphasis on revegetation research, computer decision-making programs, and investigation of the biology and ecology of problem weed species.

The U.S. Department of Agriculture Involvement

The weed and brush problems on Southwest rangelands were large enough to cause the USDA to establish a cooperative program with the Texas Agricultural Experiment Station (TAES), and to place a scientist at Spur, Texas, in September 1948. D.W. Young worked in cooperation with Charles Fisher (TAES) on control of honey mesquite (131, 132, 133, 134, 135, 136, 137, 226, 227, 228, 229, 230, 231, 232). Dr. Young moved from the USDA, Bureau of Plant Industry, Beltsville, MD, where he had served as an Assistant Agronomist. By 1950, Dr. Young expanded his research to include control of salt cedar, red-berry juniper, pricklypear cactus, catclaw, johnson grass, yucca, and lotebush condalia. Dr. Young left Texas to join Iowa State University, Ames, Iowa, in the early 1950s. He was replaced by Mr. Bill Phillips, Associate Agronomist, USDA, Bureau of Plant Industry, in 1951 at Spur.

W.M. Phillips reported in the 1951 annual report that cooperative work with TAES had resulted in experimental tests on more than 15,000 acres at 27 locations for control of mesquite. The tests included a wide range of mesquite growth types, soil moisture, season of application, and weather conditions at time of treatment. Tests extended from Falfurrias, Texas, in the south to Clarendon on the north, and from Henrietta on the east to Odessa on the west. Test areas ranged from 160 to 1500 acres at each location.

W.M. Phillips transferred from Texas to the Kansas Agricultural Experiment Station and the position was not filled at Spur by the USDA. However, Dr. Richard Behrens, Plant Physiologist, Bureau of Plant Industry, arrived in College Station, Texas, in 1952 to study the physiological aspects of mesquite control and work on related projects and mesquite control at Spur. Dr. Behrens was housed in the Plant Physiology and Pathology Department.

C. E. Fisher began work on mesquite control in 1937, and by 1953 data developed by TAES and USDA cooperators indicated that the low volatile esters of 2,4,5-T were relatively effective in controlling mesquite. Rates of 2/3 and 3/4 pound per acre in 1 gallon of diesel fuel and 3 gallons of water gave the most consistent control (141). Most effective control was obtained when treatments were made 45 to 95 days after mesquite first began to leaf out. The optimum date for treatment was 70 days after first leaves appeared. Seventeen publications on mesquite control by TAES and USDA scientists were listed in the 1953 USDA annual report.

In 1954, the USDA changed the name of the unit to Weed Investigations Section, Field Crops Research Branch, Agricultural Research Service (ARS), USDA. At College Station, Dr. Behrens completed research on herbicide screening, translocation of herbicides, and the effect of environment on herbicide response, as well as mesquite control (21, 138, 139).

Brush control research at College Station in the Range Management Department started with student projects but soon became a major experiment station project. Mr. F.W. Anderwald was appointed field leader in 1947 and continued until he became Ranch Superintendent of the Pierce Ranch in 1948. During the 1950s, TAES weed and brush control workers at College Station included Drs. Robert Darrow and Wayne McCully. At Spur, Texas, personnel in addition to C.E. Fisher included E.D. Robison and C.H. Meadors. E.D Robison joined the Spur staff in 1956 and worked until the mid-1960s when he accepted a commercial position. C.H. Meadors worked at Spur from 1951 until he resigned in 1959 to accept employment with an agricultural chemical company. P.T. Marion was an animal scientist and was promoted to superintendent of the Spur location after C.E. Fisher became superintendent of the Lubbock Station in 1957.

Dr. Richard Behrens worked from 1952 to 1958 at College Station in cooperation with TAES in the Department of Plant Physiology and Pathology, Texas A&M University. Behrens' classical paper on herbicide spray carriers published in 1956 (21) established certain basic principles of spray droplet deposit and plant toxicity and is still cited in the scientific literature. Dr. Behrens also published data on the effects of phenoxy herbicides on cotton (23). Dr. Behrens spent most of his career as a weed scientist at the University of Minnesota at St. Paul after leaving Texas. Dr. Howard Morton was also a Research Agronomist with ARS and worked with Dr. Behrens before Dr. Behrens' departure in 1958. Dr. Morton arrived in May 1957 and obtained his Ph.D. under Dr. Wayne Hall in 1961 (193). Dr. Morton continued working in the Plant Physiology and Pathology Department as a Weed Scientist until he transferred to Tucson, Arizona, in 1968. Dr. Robert Meyer, a new Ph D. Plant Physiologist from the University of Wisconsin,

joined Dr. Morton as a co-worker in 1961. The USDA-ARS group was further expanded when Dr. Morris Merkle joined the group from Cornell University in 1963 and Drs. Rod Bovey and Frank Davis from the University of Nebraska joined the group in 1964 as Weed Scientists. Dr. Fred Bouse, Agricultural Engineer, USDA-ARS, transferred from Oklahoma State University to work with the College Station ARS group that same year.

The work of Morton and Meyer in the early 1960s consisted of propagation of woody plants; evaluation of herbicides on woody plants; effect of environment on the absorption, translocation, and metabolism of herbicides in woody plants and forages; and the study of the anatomy and morphology of woody plants (184, 193, 195). The USDA-ARS, Crops Research Division, Crops Protection Research Branch, Weed Investigations - Grazing Lands was cooperative with the Texas Agricultural Experiment Station, Department of Plant Sciences and Range and Forestry, Texas A&M University at College Station, Texas. The ARS Scientists added basic research data as well as applied efforts to the overall weed and brush research program in the southwest. Primary woody plants investigated included honey mesquite, live oak, Macartney rose, and pricklypear cactus. Drs. Meyer and Morton also worked with R.H. Haas (1960-1980) in the Department of Range and Forestry on the relationship of environmental variables to the growth and development of mesquite. Dr. Haas worked in remote sensing and woody plant control from 1960 to the late 1970s. Dr. J.D. Dodd, Plant Ecologist, joined the RLEM faculty in 1963 and worked on the ecology and control of pricklypear cactus. Dr. Dodd later in his career had administrative duties in the grant program of the TAES. He retired in 1993.

In the early 1960s, expanded research in Texas, Puerto Rico, and Fort Detrick, MD, was made possible by a request from the Advanced Research Projects Agency (ARPA) of the office of the Secretary of Defense for information on the technical feasibility of defoliating jungle with herbicides in Vietnam (41). It was proposed that defoliation of vegetation paralleling roads, airfields, depots, strategic hamlets, and outposts would reduce enemy attacks and increase visibility. There were also obvious benefits of the research to improve herbicides for agriculture. The ARPA, DOD, supported research about 2 years at College Station, after which ARS supported a majority of the work. Drs. Meyer and Morton were housed in the Plant Science Department while Drs. Bovey, Davis, and Merkle were housed in the Department of Range and Forestry. Dr. Bouse was housed in the Department of Agricultural Engineering.

In 1963, ARPA-supported research got underway on brush control and chemical defoliation of woody plants. Laboratory and greenhouse work was concentrated on the influence of light on the herbicidal properties of paraquat, residue effects of various families of herbicides under field conditions, and variations in carbohydrate content of whitebrush, live oak, and mesquite. A woody plant nursery to grow plant materials and plants for herbicide studies was established. About 2000 plants of greenbriar, whitebrush, and Macartney rose, more than 1000 winged elm and mesquite, and about 500 live oak were planted in 1963. Field sites were also established at Carlos, Llano, Victoria, Refugio, and Livingston, Texas, for field evaluation of herbicides for defoliation and plant kill. Woody plants included yaupon, post oak, blackjack oak, and winged elm at Carlos; whitebrush at Llano; live oak at Victoria; huisache and mesquite at Refugio; and mixed hardwood species at Livingston, Texas. In addition to the ARPA research, Morton and Meyer completed cooperative research between TAES and USDA-ARS on pricklypear cactus control, woody plant propagation, mesquite growth, and anatomical studies and herbicide evaluations on seedling mesquite. The results were reported in their 1963 annual report and outside publications (22, 173, 194).

In 1964, Dr. Bovey was assigned the Victoria and Refugio field sites; Dr. Davis the Carlos site; Dr. Meyer the Llano site; Dr. Merkle the Livingston; area and Dr. Morton the woody plant nursery and greenhouse. Two new greenhouses and a metal laboratory building were constructed for treating plants with herbicides, sample preparation, and chemical analytical work. Laboratory, greenhouse and nursery studies were done on a cooperative basis between scientists as needs and interests dictated. The opportunity for each scientist to concentrate on one or few woody species resulted in best progress. Research continued on evaluation of herbicides on woody plants, propagation of woody plants, absorption and translocation of herbicides, mode of action and fate of herbicides in woody and forage plants, development of new herbicides and analytical methods, application and distribution of herbicides, visibility measurements in brush, herbicide effects on plant and animal populations, and anatomy and morphology of woody plants. Dr. L.F. Bouse cooperated with S.K. Lehman (1964-66) in Range and Forestry on spray distribution pattern studies. F.S. Davis and R.W. Bovey worked with S.K. Lehman on yaupon, winged elm, and live

oak control. Dr. M.G. Merkle cooperated with Dr. A.F. Isbell in Chemistry on chemical synthesis and molecular configuration studies. R.W. Bovey cooperated with Dr. U.G. Whitehouse of the Biochemistry Department on herbicide effects on ultra cell structure using the electron microscope. Dr. Morton cooperated with E.D. Robison at Spur on 2,4,5-T enhancement studies on mesquite and residues in forage. The young USDA-ARS staff was a well-trained and powerful research force ready to conquer the brush problem.

The mid-1960s were productive years and exciting times because of the opportunities, resources, and expertise available. Data in 1965 showed that picloram or picloram plus 2,4,5-T and/or paraquat was highly effective in defoliating and killing brush (40, 67). Gas chromatographic analyses were developed for picloram and 2,4,5-T and showed that picloram was more mobile in bean plants than 2,4,5-T (116, 171). A thermoelectric method was developed for measuring moisture stress in plants, and when combined with gas chromatography analysis could monitor herbicide movement(168).

Data in 1966 indicated that picloram entered most woody plants faster and in greater amounts than 2,4,5,-T (117). Gas chromatographic and radioisotopic analyses of 2,4,5-T in mesquite gave similar results when identical procedures were used (196). Picloram occurred in lethal amounts in greenhouse-grown huisache within 24 hours after treatment and persisted for at least 30 days in the plants with little or no apparent breakdown (66). Leaching of picloram is an important means of dissipation of picloram from the upper soil profile. Photodecomposition of picloram occurred if the herbicide remained on the soil surface for long periods of time (170).

In 1967 several significant changes occurred. Partial financial support by ARPA, DOD, terminated in March 1967, but the loss was replaced by USDA-ARS. Dr. J.R. Baur, plant physiologist, joined the brush research group to fill the vacancy created by Dr. M.G. Merkle's resignation in 1966. Dr. C.R. Swanson transferred from Fargo, ND, to fill the vacancy of F.S. Davis who accepted a foreign assignment with the University of Nebraska. Dr. R.W. Bovey, Research Agronomist, was transferred to Puerto Rico for 1 year to conduct research on defoliation and control of tropical vegetation. Mr. Robert Hursey, technician and graduate assistant for nearly 4 years, received the M.S. degree from Texas A&M University in Plant Physiology and accepted a position to work on a Ph.D. in Forestry at the University of Idaho.

Ongoing research consisted of evaluation of new herbicides, herbicide combinations, and herbicide diluents and formulations on woody plant phytotoxicity in the nursery and field. Laboratory studies consisted of plant enzyme effects on herbicides, herbicide concentrations and effects in subcellular fractions, uptake and transport of herbicides, effect of herbicides on ultrastructure of chloroplasts, herbicide residues and lethal effects in plants, and herbicide effects on anatomy and morphology. Mesquite seedlings were analyzed for the presence of sucrose, raffinose, and stachyose. Only sucrose was found.

In July 1968, Dr. R.W. Bovey transferred after 1 year from the Federal Experiment Station, Mayaguez, Puerto Rico, and was assigned project leader of the College Station brush research group replacing Dr. H.L. Morton who had served as team leader for several years. Dr. Morton transferred to Tucson, AZ, in August 1968 to fill the vacancy created by Dr. Fred H. Tschirley. Dr. C.R. Swanson, Plant Physiologist, transferred in July 1968 from College Station, Texas, to the Southern Weed Science Laboratory at Stoneville, Mississippi, to become Director. All the personnel changes in 1967 and 1968 reduced the Weed Investigations staff to Drs. Baur, Bovey, and Meyer.

During 1968 electron microscopy studies on mesquite leaves indicated that paraquat disrupted the plasmalemma followed by rupturing of chloroplast (19). Uptake of picloram by potato tuber discis was metabolic and physical (11, 211). Picloram applied to roots of seedling huisache and mesquite stimulated ethlene production (9). Picloram caused loss of leaf movement similar to fumigation with ethylene. Soil applications of picloram may not be effective in mesquite compared with huisache because in seedling mesquite picloram was redistributed and eventually lost over a 5-day period, whereas, neither redistribution nor loss occurred in huisache (10).

Mixtures of 2,4,5-T plus picloram applied by aircraft gave best brush control and grass release in east Texas timberlands (169), but picloram alone was best on whitebrush (191). Aerial application of picloram or picloram plus 2,4,5-T controlled live oak in south Texas after spring or fall treatment (76, 92). Fall applicators also controlled huisache, blackbrush, whitebrush, catclaw, spiney hackberry, hog-plum, pricklypear cactus, and tasajillo. Texas persimmon, wolfberry, agarito, yucca, lotebush, and mesquite were resistant to these treatments. Application of picloram pellets at several locations and dates controlled live oak, huisache, and yaupon, but not mesquite (77, 80).

Evaluations made in 1969 indicated that picloram and picloram plus 2,4,5-T controlled yaupon, post oak, blackjack oak, and winged elm (78). The potassium salt of picloram was usually more effective than the isooctyl ester of picloram for brush control in Texas (84). Laboratory studies showed rapid loss of the ester under UV light and high temperatures. Residues of picloram in yaupon and grass applied to a watershed diminished rapidly within the first 6 months after treatment (14, 15, 18, 20). Small amounts of picloram were detected up to 8 feet deep in the soil and < 6 ppb of picloram were detected in water by 3.5 months after treatment. Picloram at 100 and 1000 ppb added once in water decreased dry weights of crop plants but some crops were stimulated in growth at 10 ppb or less (16). Soluble protein increased in cotton and cowpea.

In 1970, hand defoliation of brush indicated that about 2 days were required for leaves to transport maximum amounts of 2,4,5-T, picloram, or picloram plus 2,4,5-T into stems and roots for best control (189). Application of 1 pound per acre of picloram to a 15-acre watershed disappeared from the treated grass and woody vegetation in 1 year. Minute concentrations were found in soil and runoff water (14, 15, 18, 20).

The years of 1968, 1969, and 1970 were highly productive with a good balance of laboratory and field studies as evident in the large numbers of publications, including Dr. Bovey's year in Puerto Rico from 1967 to 1968. Dr. Bovey worked with Dr. Robert Darrow and J. Ray Frank, USDA-ARS, Ft. Detrick, MD, while in Puerto Rico.

During this time, the Texas Technological College at Lubbock, Texas, also received special state appropriations beginning in 1967-68 to intensify their brush control research program. Their efforts were also supported by additional private grant funds and materials which made them a full-fledged partner in range improvement.

Dr. Frank Davis returned from his Colombia, S.A., assignment in early 1969 to become a professor and research scientist in the Range Science Department, Texas A&M University, for about 2 years before resigning. Dr. Charles Leinweber became department head in 1960 and was active during this time. Dr. Charles Scifres also joined the Range Science faculty later in 1969 after spending about a year at the Texas Agricultural Experiment Station, Texas A&M University at Lubbock. Dr. Scifres resigned in 1988 to assume administrative responsibilities at Oklahoma State University.

In early 1970, Dr. Robert Meyer transferred from the Plant Science Department at Texas A&M University to Range Science and Dr. Darrel Baker worked with Drs. Joe Baur and Rod Bovey in a post doctorate position after completing his Ph.D. at Texas A&M University in Plant Physiology. Dr. Baker worked on picloram residues in soil.

In the 1970s, work was continued on mesquite, huisache, Macartney rose, live oak whitebrush, and other woody plants (53, 78, 87, 90, 91, 142, 174, 175, 176, 177, 178, 186, 188, 189, 206). Subsoil spray applications of herbicides showed promise with chisel plows (53, 93, 175, 176, 177). Work was also done on 2,4,5-T residues at five locations in Texas (50). Picloram and 2,4,5-T were monitored in surface runoff and subsurface water as well as in soils and vegetation (43, 60, 61). In the laboratory, soybean and cottonwood tissue cultures were used to determine the phytotoxicity of picloram, 2,4,5-T, and dicamba (81, 126). Picloram and 2,4,5-T were more resistant to thermal and UV light degradation than dicamba (12, 17). Picloram was found to affect cytoptasmic protein synthesis (7, 8). Considerable effort was also made to determine the environmental effects on growth and development of mesquite and its response to herbicides (185, 190).

Brush control work with tebuthuron was first initiated by ARS scientists in January 1972. It proved to be a very effective soil-applied herbicide that could be applied in granular form by hand and by ground or aerial equipment. Work was also done to investigate its physiological effect and fate in the environment (13, 62, 86). Hexazinone, triclopyr, clopyralid, and many other herbicides were also investigated for brush management in the 1970s (178). Triclopyr was considered a possible replacement for 2,4,5-T (45, 59, 83). Weed control for forage establishment on pasture and rangeland was initiated in the late 1970s. Dr. Meyer also published on the morphology and anatomy of Texas persimmon (172).

Dr. Bovey was assigned as Special Advisor, Office of the Secretary, U.S. Department of Agriculture, from 1972 to 1974 in preparing defense for the use of 2,4,5-T on rangelands for public hearing called by the EPA in 1974. The work involved preparation of pre-trial briefs, documentation, correspondence, and statements of testimony. It also included review of the literature, consultation with other experts, and attending numerous conferences and seminars. The work culminated in publication by the Texas Agricultural Experiment Station of 10 bibliographies on the phenoxy herbicides (46, 47, 48, 49, 120, 121, 123, 124, 125), other supporting documents (64, 111, 119), and a book

(42) published by John Wiley & Sons, New York, NY. G.O. Hoffman, C.J. Scifres, J.L. Schuster, and R.W. Bovey also participated in a national effort to assess the benefits of 2,4,5-T (64). Despite gallant efforts by federal, state, and private industry, the EPA announced emergency suspension on February 28, 1979, of 2,4,5-T products on forests, rights-of-way, and pastures and suspension of silvex products for the same uses plus home, aquatic, and recreation areas. Cancellation of these products occurred in 1985 by the U.S. District Court, Washington, D.C.

Dr. Charles Leinweber stepped down as head of Range Science in 1971 and retired in 1976. Dr. Wayne McCully was acting head during 1971 and 1972 until the position was filled by Dr. Joe Schuster of the Texas Technological College. The USDA-ARS was reorganized in 1972. Dr. Dayton Klingman, Weed Investigations, Grazing Lands, Crops Protection Research Branch, Crops Research Division, Beltsville, MD, who had been our leader for many years, and Dr. W.B. Ennis, Jr., Chief, Crop Protection Research Branch, no longer supervised our group at College Station, Texas. ARS was decentralized and reorganized by region. Our region became the Oklahoma-Texas Area, and later the Southern Plains Area in 1984 after adding Arkansas and New Mexico, with Dr. Rex Johnston as Area Director. Early on, the area reported to a regional administrator, Dr. A.W. Cooper, located in New Orleans, Louisiana. Dr. L.F. Bouse, Agricultural Engineer at College Station, joined the Brush Control Research Unit in 1972. In 1973 Dr. Jim Carlton from Mississippi State transferred to our group and was supervised by Dr. Bouse. During the same years, the project acquired an aircraft pilot, Andy Anderson, and a Cessna agricultural aircraft from Beltsville, Maryland. Drs. Bouse and Carlton worked with Dr. Bovey, Research Leader of the Brush Control Research Unit, until late 1978 when the engineering group was assigned its own research unit with Dr. Bouse as Research Leader.

In addition to the strong research program at Texas Technological College at Lubbock, the Texas Agricultural Experiment Station significantly strengthened the weed and brush control effort in Texas by hiring Mr. Bobby Cross, Research Associate, in 1968 and rehiring Cecil Meadors in 1969 for north Texas. Mr. Meadors retired in 1991. Mr. Harold Weidemann, Agricultural Engineer, was hired in late 1969 to develop aerial and mechanical control equipment and revegetation practices. Dr. Pete Jacoby also joined the faculty at Vernon, Texas, in 1976 to continue research on mesquite management and associated weed problems with herbicides and prescribed burning. Dr. Jacoby served as an Extension Range Specialist from 1970 to 1973 at Ft. Stockton, Texas, and resigned in 1993 to join the Extension Administration, University of Nebraska at North Platte. Dr. Jim Ansley, Plant Physiologist, joined the Vernon group in 1983 to work with Dr. Jacoby and is continuing mesquite management and physiology research.

Dr. Darrell Ueckert joined the Texas Agricultural Experiment Station staff at San Angelo in 1976 to work on brush management and revegetation of rangelands. Dr. Steve Whisenant worked with Dr. Ueckert as a Research Associate from 1976 to 1980 at San Angelo. Dr. Whisenant resided in College Station from 1980 to 1982 to finish his Ph.D. in Range Science with Dr. Charles Scifres. After spending 6 years at Brigham Young University, Provo, Utah, Dr. Whisenant joined the Range Science faculty at College Station in 1988. Dr. Whisenant works in rangeland restoration research. Mr. Wayne Hamilton also joined the faculty at College Station in 1976 and works in rangeland improvement.

During the 1970s and early 1980s ARS also strengthened its brush management programs by the addition of several new staff in biological brush control and brush ecology at Temple, Texas. Dr. Jack DeLoach transferred from the Hurlingham biocontrol laboratory in Argentina to Temple in 1974 to work on biological control of brush with insects. In 1977, Dr. Herman Mayeux finished his Ph.D. at Texas A&M University in Range Science and accepted a brush control position dealing with herbicide use and fate in the environment. Dr. Mayeux later worked in brush ecology with Dr. Hyrum Johnson. Dr. Hyrum Johnson joined the Temple ARS brush ecology group in 1980 from BLM at Riverside, California. In the same year, Mr. Paul Bolt joined the Temple group from Rome, Italy, working on range weed control. Dr. James Cuda, an Entomology graduate of Texas A&M University, worked at Temple with the biocontrol group in the mid-1980s. Dr. Wayne Polley also joined the Temple ARS group in 1988 in a post doctorate position and was later converted to a permanent position working in ecophysiology. Dr. C.R. Swanson, Plant Physiologist, ARS, joined the Temple staff in brush management in 1978 from administration in New Orleans, Louisiana, to become Research Leader of the Temple group. Dr. Swanson proposed working on herbicide metabolism in mesquite and huisache but retired in 1979. One of Dr. Swanson's final tasks was to write an in-depth assessment of research needs in rangeland brush and weed control (210). Dr. Swanson suggested herbicide appli-

cation technology be continued but also to expand critically needed basic information on ecology, physiology, and biochemical research on weed and brush plus establish feasibility of biological control. Dr. Swanson suggested continuing the present level of funding and staffing but encouraged basic studies that would complement practical state programs.

The untimely death of Dr. Joe Baur, Plant Physiologist (ARS), in 1979 significantly reduced the herbicide physiology, herbicide residue, revegetation, and field research at College Station. Drs. Bovey and Meyer constituted the group after the loss of Dr. Baur, although cooperative work was continued with Drs. Bouse and Carlton, scientists at Temple, and other state cooperators in application technology research. In 1982 Dr. Bovey was assigned Research Leader of the Temple group in addition to College Station, which was named the Grassland Protection Research unit of ARS. Dr. Bovey continued as Research Leader until 1988.

In February 1982 an ARS Research planning conference was convened for rangelands and related research at College Station (2). All appropriate USDA-ARS, scientists, local and key state researchers, and Extension specialists participated, as well as the appropriate national program leaders.

Twenty-five ARS and state scientists met in College Station on February 24 and 25, 1982, to plan national and location research priorities on weed and brush control on rangeland and related integrated practices. Three National Research Program Leaders attended the conference including Drs. Shaw, Carlson, and Drea. The welcome and introductions were given by Dr. Bovey. Dr. Rex Johnston, Area Director (Oklahoma-Texas Area), gave a brief history and significance of grassland research. Dr. Shaw, NRPL for Weed Control and Agricultural Chemicals Technology, outlined the objectives of the conference.

Each researcher gave a short presentation about his research program to bring participants up-to-date and to provide an information base for future planning. Special emphasis was given to forage establishment and maintenance with or after weed or brush control and related practices. Presentations were also given by Dr. Jack Witz, Agricultural Engineer, on the use of computer modeling in research and by Dr. B.J. Ragsdale, Extension Range Management Specialist, on technology transfer from researchers to land managers. A tremendous volume of quality information was presented by the ARS scientists and guest speakers.

On February 25, 1982, national and location research priorities were established by the conference participants. The researchers were asked to submit location research priorities prior to the conference. At the conference all location priorities were rated by each scientist and the data summarized. The national research priorities were established, ranked and presented in priority sequence as follows:

Priority 1. Study the biology, ecology, and edaphic factors as the basis for control technology.

Priority 2. Brush and weed control on grazing lands with special emphasis on improving desirable vegetation.

Priority 3. Absorption/translocation/metabolism of herbicides in weeds, brush and forage plants.

Priority 4. Economic assessment of weeds and brush control technology.

Priority 5. Develop improved herbicide formulations and delivery systems technology.

Priority 6. Systems technology for vegetation manipulation, management and multiple use objectives.

Priority 7. Foreign exploration and cooperation for biological control of weeds and brush.

Priority 8. Evaluate multiple use strategies in biological control of weeds and brush.

Priority 9. Develop and use models to improve weed and brush technology.

Priority 10. Livestock grazing management to manipulate and manage weedy rangelands.

Policy Issue: It was also suggested that Special Strike Force Funds be made available to support high priority research when needed to accelerate and complete important technological developments.

The group also unanimously agreed more engineering technology was needed in our programs and every effort should be made to employ engineers to support ARS research and missions.

With limited funds and personnel, not all priorities could be pursued, but in Texas priorities 1, 2, 3, 4, 5, and 7 were well researched by ARS and state

scientists in the 1980s. As indicated, several new ARS scientists were added to the Temple program in the 1980s, which complemented the ARS program at College Station and statewide programs of Texas A&M University and Texas Tech.

ARS scientists at College Station constructed and worked with a tractor mounted carpeted roller to apply herbicides to weeds and brush on rangelands (56). However, Dr. Herman Mayeux is credited with developing the first working model and developing the procedures for honey mesquite control (163). The device was very useful where drift from foliar spray applications of herbicides could have injured susceptible crop plants. The early 1980s is also when the sulfonylurea compounds became available from E.I. DuPont De Nemours & Co., Inc. Wilmington, Delaware, for crop and grazing land use. These compounds are unique in that extremely small amounts (ounces or fractions of an ounce per hectare) are required for weed control. These compounds have gained widespread usage in cropland and for certain weeds on rangelands. They have also been useful for weed control in the Conservation Reserve Program. The 1980s and 1990s were very productive years with continued work in fate of herbicides in the environment and refining herbicide control practices. Considerable work was completed on evaluation of soil-applied herbicides such as tebutheron and hexazinone (44, 53, 86, 87, 88, 166, 175, 176, 178, 179, 180, 182, 187, 206). Work was initiated on evaluation of herbicides for weed control in newly established forage crops (51, 52, 69, 79, 82, 89, 94). Combinations of herbicides were evaluated for honey mesquite control for synergism and optimum rate. Since new herbicides were not as common for grazing lands compared to cropland, attempts were made to increase available commercial herbicide effect by herbicide mixtures, the use of growth regulators, surfactants, and other adjuvants (54, 55, 57, 58, 63, 68, 70, 71, 73, 74, 75, 85).

Investigations were conducted to answer why certain herbicides were more effective than others on honey mesquite (54, 70, 75, 181). Work with the ARS Agricultural Engineers was done to determine the important factors in spray deposition in the laboratory and field (72, 73, 85, 218). Herbicide forms were evaluated as well as diluents (68, 74). Dr. S.G. Whisenant worked with Dr. Bovey on many of these studies.

Work was also continued on the biology and control of common pasture and rangeland weeds by Dr. Robert Meyer, but his retirement in 1988 curtailed the work. Work has continued on CO_2 and other environmental effects on weeds and brush by the ARS Temple group, as well as biological control.

Dr. Pete Jacoby resigned from the TAES in 1993 to take a job as an Administrator in the Extension Service at North Platte, Nebraska. Drs. Bovey and Bouse retired from ARS in 1994 and Dr. Herman Mayeux at Temple, Texas, became program leader for Range in 1996 and is stationed in Beltsville, MD.

Some significant accomplishments of ARS-TAES included:

1. Investigations with TAES established by 1953 that 2,4,5-T effectively controlled honey mesquite.
2. Dr. Behren's classical paper published in 1956 on spray droplet spacing, diluents, and phytotoxicity on honey mesquite.
3. Dr. Morton's work on metabolism of 2,4,5-T in honey mesquite in 1961.
4. Dr. Meyer's detailed description of the anatomy and morphology of honey mesquite was published in 1971.
5. Development of analytical procedures for picloram in soils, vegetation, and water sources in 1966.
6. Determination that certain herbicide combinations such as picloram plus 2,4,5-T (1:1 ratio) could increase control (synergism) of honey mesquite in 1968.
7. Development of control measures for problem woody plants with herbicides in tropical and subtropical areas (1969).
8. First to work with controlled release herbicides for weed and brush control in 1972.
9. Extensive research on persistence of herbicides in grasslands.
10. Extensive research on the mode-of-action, absorption, and translocation of herbicides in herbaceous and woody plants.
11. Development of tebuthurion for weed and brush control (1978).
12. Initial work to show that 1:1 mixtures of clopyralid plus picloram or triclopyr were highly effective on honey mesquite (1985).
13. Defense for use of 2,4,5-T in agriculture and Dr. Bovey was senior author of an extensive text on the subject (1980).

14. Establishment that clopyralid was absorbed and transported in significantly greater concentrations in honey mesquite than triclopyr, 2,4,5-T, or picloram (1980).
15. Documentation of the effectiveness of pelleted herbicides on a number of weeds and woody plants (1980).
16. Establishment of the effect of water soluble extracts of leaves, fruit, bark, and roots of tropical and subtropical plants on the growth of other plants (allelopathy) (1969).
17. Initial work by Dr. Mayeux to show the effectiveness of the carpeted roller herbicide applicator for honey mesquite control and other weeds (1985).
18. Initial work to show the mode of clopyralid uptake and transport of clopyralid in plants alone and after foliar application with triclopyr (1988).
19. Elucidation of the phytotoxicity and transport of different clopyralid formations in honey mesquite (1989-1990).
20. The effect of spray deposition, droplet size, spray volume, surfactant, and herbicide formulation on the phytotoxicity and transport of clopyralid in honey mesquite (1991-1994).
21. Dissipation, movement and environmental impact of herbicides on Texas rangelands (1964-1993).

ARS Application Technology Research

Weed and brush work was complemented by help from the ARS Agricultural Engineers to improve herbicide placement on soils and plants. Dr. Fred Bouse transferred from Oklahoma State University in 1964 to work with the College Station ARS weed scientists and TAES personnel to improve pesticide application. In 1972 Dr. Bouse was assigned to the Brush Control Research Unit and in 1973 Dr. Jim Carlton was transferred from Mississippi State to the ARS brush group. During the same year, an aircraft pilot, Andy Anderson, and a Cessna agricultural aircraft were transferred to the brush group from Beltsville, MD. In 1978 the engineering group was assigned its own research unit and Dr. Bouse became the Research Leader.

Although other research units and scientists in the late 1970s and 1980s (entomologists) were assigned to Dr. Bouse's group, in the 1980s the core pesticide application unit consisted of Drs. Bouse, Kirk, Stermer, Carlton, and Latheef. Drs. Kirk and Latheef were both transferred to College Station, Texas, from other locations in 1987. Dr. I.W. Kirk was Center Director, Southern Regional Research Center, USDA-ARS, New Orleans, Louisiana. Dr. M.A. Latheef arrived from Oklahoma State University where he was a Research Associate. Dr. R.A. Stermer spent most of his career with ARS at College Station and was assigned to work in the Application Technology Unit in 1986. Dr. R.W. Bovey was assigned to Dr. Bouse's group in 1988 and to the Beltsville, Maryland, Weed Science laboratory in 1991 until his retirement in 1994. Dr. Bovey, however, remained in College Station all of his career except for one year in Puerto Rico in 1967-1968. Dr. Bovey continued to work with Drs. Bouse, Stermer, and Franz in addition to weed and brush work until his retirement. Dr. Eric Franz joined the Engineering Unit in August 1989 from the ARS Aricultural Engineering Unit in Columbia, Missouri, about the same time Dr. Stermer retired. Dr. Franz passed away in 1994 after an extended illness.

An aircraft hanger and research facility was constructed at the Texas A&M University Riverside Campus in 1974, and an agricultural aircraft was transferred from APHIS in 1975. In the 1960s aerial spray research was conducted with a refurbished Gruman AgCat owned by Texas A&M University. Termination of an ARS research project on aerial application at Yakima, Washington, in 1983 resulted in the transfer of equipment, two airplanes and a helicopter, to College Station along with increased funding. Funding for expansion of an aircraft hanger, shop, and laboratory space at the Riverside Campus in 1986 brought the existing facilities to more than 18,000 square feet of enclosed space.

Work by Dr. Bouse in the mid 1960s was funded by the Department of Defense and consisted of developing improved defoliation of tropical and subtropical vegetation with herbicides. Emphasis of ARS funded programs in the late 1960s and early 1970s was on uniform droplet generation, spray drift, and penetration of aerially-applied sprays through woody plant canopies. In the early and mid 1970s, investigations were conducted on the use of foam, oils, low-pressure, and other nozzle designs and spray additives to increase recovery and reduce transport of spray droplets. In the mid- to late 1970s, research focus was on electrostatic charging of aerially applied spray, detection and measurement of airborne spray, and metering systems for applying dry herbicide formulations from aircraft. In the 1980s, research shifted to improved technology for automated measurement of aerial spray distribution, quantification of spray coverage on vegetation, herbicide pellet distribution, and factors affecting the size distribution of aerially applied spray droplets (26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 143, 144, 145, 146, 147, 149, 159, 160, 192, 215, 223, 224, 234).

Some significant accomplishments of the engineering unit as related to brush management involved:

1. Development of positive metering concepts for aerial application of granular and pelleted herbicides and identification of operational and atmospheric parameters affecting uniformity of distribution.
2. Determination of effects and physical properties of spray mixtures, operational variables, and equipment parameters on the size distribution of spray droplets using a laser-based particle measurement spectrometer.
3. Developed basic information on electrostatic charging of spray droplets by aircraft.

4. Made major advances in aerial spray deposit pattern measurement technology.
5. Made major advances in spray deposit technology measurement on plant foliage.
6. Developed machine vision algorithms and software to increase the accuracy of an image processing system used to analyze spray deposits on artificial and foliar collectors.
7. Developed spray drift sampling techniques and identified operational aircraft parameters affecting spray deposit.
8. Developed pesticide injection system technology for agricultural aircraft that minimizes operator exposure and leftover tank mix, and permits rinsing the pesticide from the system over the target field.
9. Software and hardware were developed for in-flight measurement of flow fields near an agricultural aircraft, including a pitch/yaw error indicator, data acquisition software, and mounting of hardware on a Cessna aircraft. Data indicated that nozzle type, placement, and operating conditions to minimize small droplets subject to drift be obtained for different types of agricultural aircraft.

Contributions of the Texas Agricultural Experiment Station (TAES)

Brush problems were recognized more than 100 years ago and the spread of noxious weeds on rangelands has been blamed on many factors including man's activities (233). Means to control weeds and brush have been intense the past 50 years with some successes. Darrow (115) stated that in the 1940s and 1950s the needs and accomplishments in woody plant control in Texas could be assessed by yearly acreages of brush control carried out under the Agricultural Conservation Program of the Agricultural Stabilization and Conservation Committee. From 1940 to 1950, 0.5 to 3 million acres were treated yearly and from 1950 to 1960 an average of 1 to 1.5 million acres were treated yearly. Main species controlled were mesquite, cedar, pricklypear, oak, and mixed brush. In 1951 and 1952, more than 1 million acres were treated annually but drought in the mid-1950s reduced treatment. However, from 1936 to 1959 an estimated total of 40 million acress were treated by some method. Since the 1940s and 1950s, the approach and philosophy of weed and brush control has changed dramatically. Attempts to eradicate weeds and brush in the 1950s have now changed to vegetation manipulation by a holistic approach using integrated brush management systems (IBMS) complemented with economic assessment (150).

Scientists of the TAES have produced many useful practices and data helpful to ranchers and land managers. One of the first significant foliar herbicide treatments effective on honey mesquite was 2,4,5-T, developed in the late 1940s and early 1950s (21, 23, 132, 133, 134, 135, 136, 137, 138, 139, 141, 193, 227, 228, 230, 231, 232). The investigators also included physiological responses of mesquite to herbicides, timing of application, and other factors affecting foliar sprays (132, 134, 136, 193, 227, 231). Individual plant treatments with herbicides and/or diesel oil applied to cut surfaces (131), or as basal treatment (226), were also investigated in the late 1940s. Concurrently, mechanical, chemical, burning, and grazing practices were described for the control of oak and associated species in the post oak-blackjack oak areas of Texas (113, 114). Recommended individual plant treatment with herbicides in addition to foliage or aerial spraying with 2,4,5-T or silvex included basal trunk spray, stump spray, frill spray, trunk injection, and soil injections with monuron or fenuron. Fenuron pellets were adapted for oak control on sandy soils. Goat grazing was also mentioned as an effective and economical method of sprout and underbrush control on cleared oak areas.

Another significant development in chemical control of honey mesquite was the 1:1 ratio of picloram plus 2,4,5-T discovered by E.D. Robison (200) and developed by other investigations (65, 118, 140, 155). This development lead to other herbicide combinations for honey mesquite control such as 1:1 mixtures of picloram plus dicamba (174, 202).

In the late 1970s triclopyr and clopyralid were found effective in controlling honey mesquite (45, 87, 156, 157, 158). Data indicated that triclopyr was equal to or slightly better than 2,4,5,-T, whereas clopyralid was more effective than 2,4,5-T in controlling honey mesquite. Jacoby et al. (158) in west Texas showed that clopyralid alone or with equal ratios of 2,4,5-T killed more honey mesquite than combinations of picloram plus dicamba, picloram plus 2,4,5-T, picloram plus triclopyr, dicamba plus 2,4,5-T, or 2,4,5-T or triclopyr applied alone. Bovey et al. (59) in east Texas showed that clopyralid, or clopyralid plus picloram, or triclopyr at equal rates were more effective than picloram plus 2,4,5-T, picloram plus triclopyr, picloram plus dicamba, triclopyr plus 2,4,5-T, or triclopyr plus dicamba. The clopyralid plus triclopyr mixture is synergistic (57, 58) and results in increased transport of clopyralid into honey mesquite when applied in clopyralid plus triclopyr mixtures (72).

Recent strategies in mesquite control in west Texas to significantly reduce cost and herbicide usage involves application of foliar sprays of clopyralid plus triclopyr as individual plant treatments to regrowth mesquite 4 to 6 years following prescribed burning (213). This method kills about 90 percent of the mesquite plants and reduces costs more than 50 percent compared with conventional aerial spraying. Individual plants can also be treated without burning but this treatment is successful on trees no taller than 6 feet.

Extremely low cost treatments can also be done with about 90 percent root kill using low-volume basal sprays (213). This method involves a special adjustable cone nozzle to apply reduced triclopyr and diesel fuel rates.

Dr. Ueckert, in addition to mesquite control, has contributed to research on biological control, weed and brush control with herbicides, prescribed burning, and grassland restoration (212, 217).

Dr. J.D. Dodd joined the Rangeland Ecology and Management Department in 1963 and worked on the ecology and control of pricklypear cactus and other plant species in south Texas (127). Both mechanical and chemical control methods were developed. In addition to research, Dr. Dodd also had teaching responsibilities and joined the TAES administrative faculty late in his career. He retired in 1993. Dr. Ueckert presently works on the ecology, physiology, and control of pricklypear cactus. He discovered that prescribed fire during winter followed by aerial application of picloram at 1/8 to 1/2 pound per acre around May 1 resulted in nearly complete pricklypear control (214). Another strategy involves utilizing two prescribed winter fires 6 to 10 years apart to reduce pricklypear abundance. On about May 1 following the second fire, high-volume sprays of 1 percent picloram applied to individual plants results in almost complete control and reduces cost by more than 50 percent compared with conventional aerial spraying.

Scifres et al. (205) worked on the concept of grid placement of karbutilate spheres (pellets) by hand and aerial application to determine optimum spacing for brush control and minimum effect on desirable vegetation. Karbutilate residues were also investigated to determine karbutilate movement and dissipation (197). A temporary effect on desirable vegetation occurred only at the point of contact of the pellet with the soil. Another interesting contribution is the variable herbicide rate pattern designed to reduce cost, improve botanical diversity, and improve the livestock and wildlife habitat (201). Design is dependant upon weed species to be controlled, wildlife species present, and environment. Dr. Scifres made many contributions to weed and brush control and rangeland improvements in Texas and is presently Dean of Agriculture at the University of Arkansas, Fayetteville.

A noteworthy advance in mechanical control of brush is the tractor mounted grubber developed by Wiedemann et al. (221, 223) to control redberry juniper, Ashe juniper, and other small weed trees on rangelands. Wiedemann and Cross (222) also developed a disk chain with a triangular pulling configuration that reduced draft requirements by 36 percent and increased the operating width by 23 percent compared with the two-tractor diagonal pulling method. The device is cost effective for preparing seedbeds on rough, log-littered, and root-plowed rangeland. H.T. Wiedemann and B.T. Cross are presently employed by TAES at Vernon, Texas.

Dr. Henry Wright, Texas Tech University, and his co-workers were leaders in west Texas in the late 1970s in use of fire for rangeland vegetation manipulation (150, 225). TAES scientists also contributed significantly to the literature especially in south Texas. Box and White (95) published on fall and winter burning of south Texas brush ranges. Pretreatment included shredding, chopping, scalping, root plowing, and root plowing plus raking. Fall burned areas produced the most grass; winter burned areas contained the most forbs. Dodd and Holtz (128) published on the integration of burning with mechanical control in south Texas grasslands. Following Dodd, Scifres and co-workers (including Dr. Herman Mayeux, Wayne Hamilton, D.L. Drawe, and others) published several papers on prescribed burning in south Texas and Scifres and Hamilton, 1993, published a book "Prescribed burning for brushland management." Dr. Ueckert and Steve Whisenant also contributed significant data to the literature. Prescribed burning has become an important established practice in Texas rangeland management (150, 203, 209). Extension personnel have also greatly contributed to its development (150).

An important aspect of weed management on rangelands is economic assessment. Dr. R.E. Whitson worked from 1974 to 1982 and Dr. J.R. Conners from 1981 to the present in providing this expertise. Numerous papers have been published (150, 167, 208, 219, 220) in addition to those sited here. Dr. Conners is a key member of the IBMS group and RLEM Department. Dr. R.E. Whitson became head of the RLEM Department in 1993.

Integrated brush management systems (IBMS) evolved from research in weed and brush management prior to the 1980s. IBMS provides manipulation of rangeland vegetation through a holistic approach that considers and incorporates the major interactions with the system (150). Major development of IMBS occurred in Texas in the early 1980s as a result of efforts by Scifres and co-workers (204, 207, 208, 209). IBMS are designed to enhance responses of rangeland resources as a whole over many years rather than brush control response from a single treatment for a few years (150). Present co-workers in IBMS not mentioned heretofore are Dr. J.W. Stuth (RLEM), faculty member since 1975, and J.M. Inglis, professor in the Department of Wildlife and Fisheries Sciences.

EXSEL (a computer based expert brush and weed control program) (151) was developed through a cooperative effort of TAES and TAEX to assist in selection of appropriate control technology for a target species based on predicted efficacy of the treatment. Users receive instructions for treatment application and guidance on post-treatment response from target species and associated vegetation. The system requires a minimum of data input to perform treatment selection accurately and allows for easy updating to add species, technologies, regulations, responses or other information as it becomes available.

Present and past faculty who have made contributions to weed and brush control through teaching or research include Drs. J.L. Schuster, F.E. Smeins, M.M. Kothmann, C.A. Taylor, C. Call, D.D. Briske, S.L. Hatch, R.W. Knight, T.C. Thurow, T.W. Boutton, S.R. Archer, M.K. Owens, R. J. Ansley, J.R. Cox, R.K. Heitschmidt, H.D. Blackburn, S.F. Zitzer, and J. Mutz. Dr. D.P. Sheehy was a visiting assistant professor from 1989 to 1991 and Dr. Bob Lyons from 1992 to 1994. Recent work by Steve Archer and co-workers in shrub ecology has been useful in determining why weed and brush infestations occur and reasons for their persistence and effects (5, 6, 96, 97, 198).

Water relations and water use patterns of honey mesquite have been investigated in relation to brush management (3, 4, 98, 112, 129, 130, 161). Herbage production and water yield have also been investigated where herbicides have been used (153, 154, 199). These data have been highly useful in learning more about the influences of water on mesquite growth and possible benefits of control programs.

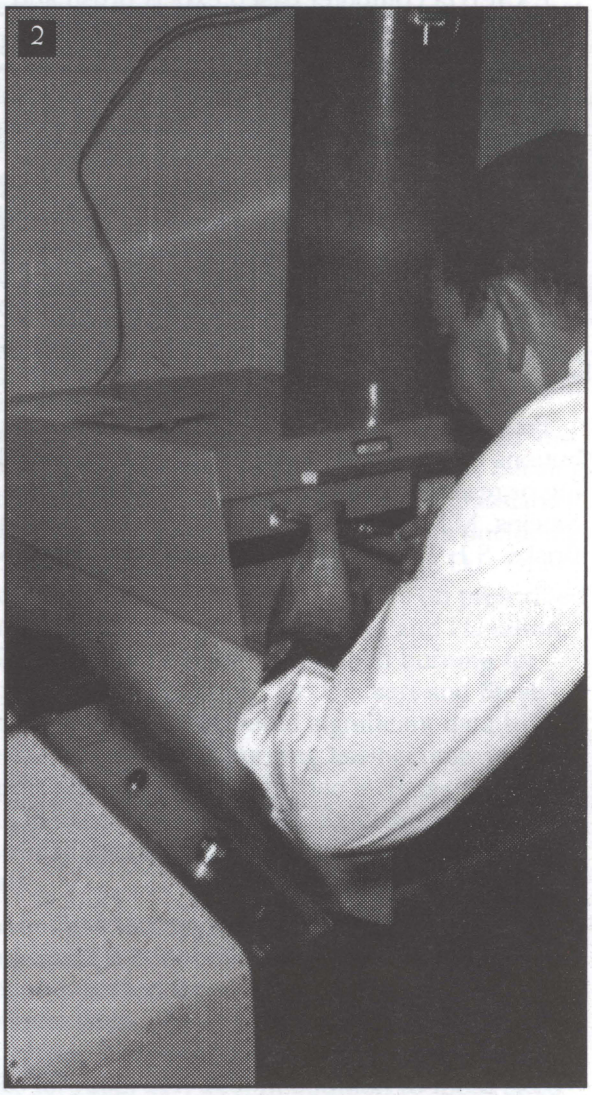
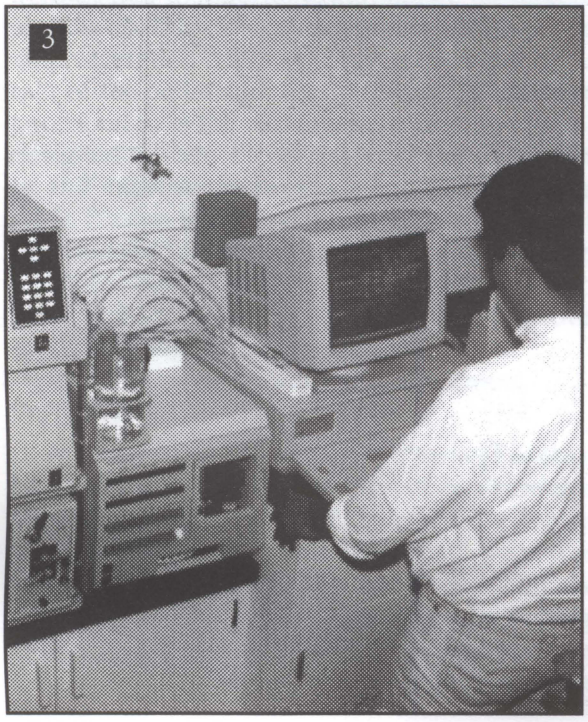


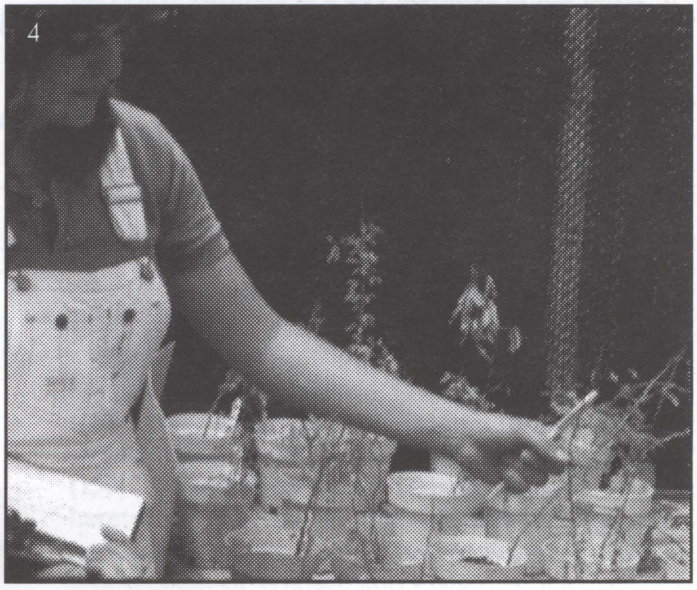
Figure 1. Sampling soils for herbicide residues.

Figure 2. Gas chromatography instrumentation for measuring herbicide in plants, soils or water.

Figure 3. HPLC instrumentation for measuring herbicide in plants, soils or water.

Figure 4. Greenhouse evaluations of honey mesquite control with herbicides.





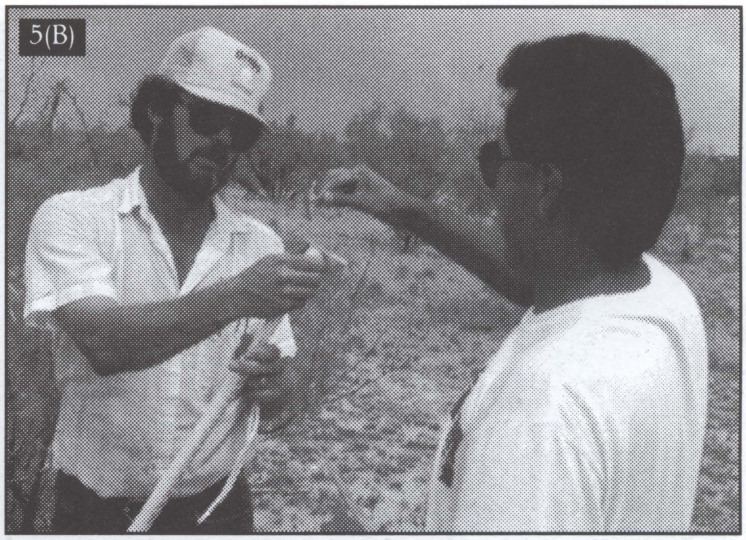


Figure 5. (A) Aerial application of herbicide for brush control. (B) Sampling spray deposit from aircraft.

Figure 6. Sampling herbicide-treated areas for forage production and herbicide residues.

Figure 7. Evaluating herbicide residues on water sheds and in runoff water.

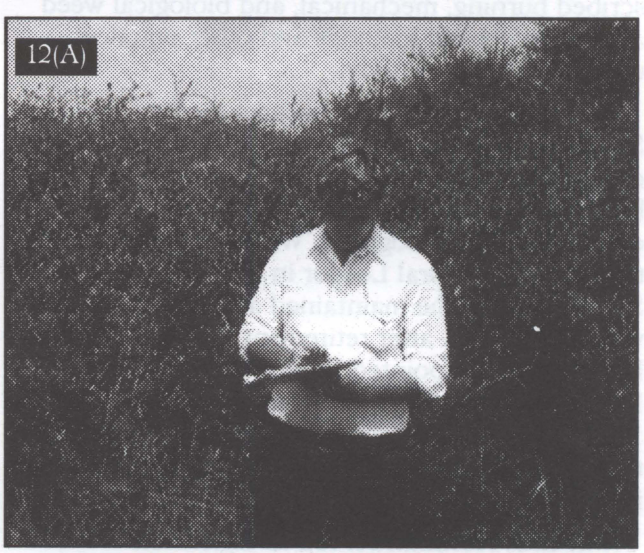
Figure 8. (A) Evaluating herbicide movement through the soil profile in a lysimeter. (B) Water collecting instruments below the lysimeter

Figure 9. (A) Growing live oaks in a woody plant nursery for herbicide trials. (B) Five-year-old huisache trees in a woody plant nursery

Figure 10 (A) Large honey mesquite tree. (B) Seed production from honey mesquite trees. Livestock can reinfest grazing lands as seeds pass through their digestive tracts.

Figure 11. Control of McCartney rose with picloram applied by aircraft.

Figure 12. (A) Untreated live oak on the Gulf Coast of Texas. (B) Live oak control 2 years after aerial application of pelleted tebuthurion. Note the release of grass species.



The Extension Service in Rangeland Ecology and Management

The Texas Agricultural Extension Service plays an essential role in management of weeds and brush on rangelands. This is accomplished by technology transfer to ranchers and users of critical information in written and oral form. Only personnel in the Rangeland Ecology and Management Department and associated Extension Specialists located throughout the state have been included, although Extension Specialists in Wildlife and Fisheries Sciences, Soil and Crop Science, Veterinary Medicine, Animal Science, and other disciplines have played a complementary role.

The Extension Service is charged with providing information to the public on rangeland management including plant identification, weed and brush control, range nutrition, watershed management, grazing management, wildlife management, restoration ecology, economics, and other educational programs vital to rancher success.

Weed and brush control programs are integrated with other management decisions and most practices resulted from numerous demonstrations in the field under many conditions. This has resulted from Extension personnel testing or using data from scientific research from state, federal, private industry, or individuals working cooperatively with researchers or other Extension personnel, or by developing practices independently and/or with land managers. Extension Service personnel have developed or helped develop the chemical, prescribed burning, mechanical, and biological weed and brush control methods and other practices used on rangelands today.

Mr. A.H. (Fred) Walker became the first Range Specialist at Texas A&M University in 1947 and established range management and weed and brush demonstrations and training courses throughout Texas (1). Although Mr. Walker was promoted to State Agricultural Leader in the Extension Service in 1957, he maintained a close association with RLEM even after retirement in 1972. Dr. B.J. Ragsdale was appointed Extension Associate Range Specialist in 1958 and to Range Specialist in 1967. Dr. Ragsdale promoted Range Management through the Extension Service in Texas. He retired in 1990.

Mr. G.O. Hoffman served as Extension Specialist from 1954 to 1967 (1). He helped develop range Extension programs for youth and adults. In 1967 he was appointed Extension Range Brush and Weed Control Specialist and helped advance practices in noxious plant control. Mr. Hoffman retired in 1979, and passed away about a year later.

Mr. J.D. (Dan) Rodgers served as Extension Range Specialist from 1967 to 1980. In 1980 he accepted a job with the University of Wyoming at Laramie. In Texas, Mr. Rodgers gave leadership to state and national youth programs in range.

Dr. Tommy G. Welch was first employed at Texas A&M University in the Rangeland Ecology and Management Department from 1972 to 1974 as an Assistant Professor. From 1974 to 1979 he served as Extension Range Specialist at Vernon, Texas, but returned to College Station from 1979 to 1995. Dr. Welch also served as Associate Department Head and Program Leader for Extension in RLEM before retiring in 1995. Dr. Welch was very active in the weed and brush program.

Dr. Barron S. Rector, Extension Range Specialist in Range Nutrition, was hired in 1973 and is still very active in the RLEM Department, as is Dr. Larry D. White who transferred from Uvalde in 1993. Dr. White is Extension Range Specialist and Professor and has been employed by Texas A&M University since 1978.

Other locations for Extension Range Specialists included Corpus Christi, Ft. Stockton, San Angelo, Uvalde, and Vernon, Texas. At Corpus Christi, Dr. C. Wayne Hanselka serves as Associate Department Head and Program Leader for the Extension Range Specialists. Dr. Hanselka has been employed with Texas A&M University since 1976. In addition to his other duties, he has been active in weed and brush management on rangelands.

At Ft. Stockton, Texas, several excellent Extension Range Specialists have served including Dr. Robert Steger (1968-1970), Dr. Pete Jacoby (1970-1973), Mr. George Sultmeier (1973-1978), Dr. W.A. McGinty (1979-1995), and Dr. Charlie Hart (1995-present).

Dr. Robert Steger served the San Angelo area in the early 1970s followed by Dr. R.Q. (Jake) Landers, Jr. from 1979 to his retirement in 1994. Dr. McGinty, formerly at Ft. Stockton, relocated to San Angelo in 1995.

Dr. Larry D. White served the Uvalde Center starting in 1978 before accepting a position as Extension Range Specialist at College Station in 1993. Dr. Robert K. Lyons now serves as Extension Range Specialist at Uvalde.

Dr. Tommy G. Welch served the Vernon Center from 1970 to 1974. Mr. J.F. Cadenhead III has been active in that position since 1980. Dr. Jerry Cox also serves as an Extension Range Specialist at that location.

The Head of RLEM, Texas A&M University, has Extension Service responsibilities and works with Extension personnel within the RLEM Department. The individuals are:

Department Name	Head	Years
Range Management	L.A. Stoddart	1945-46
Range & Forestry	V.A. Young	1946-59
Range & Forestry	R.A. Darrow (Acting)	1959-60
Range Science[a]	C.L. Leinweber	1960-71
Range Science	W.G. McCully(Acting)	1971-72
Rangeland Ecol. & Mgmt.[b]	J.L. Schuster	1972-93
Rangeland Ecol. & Mgmt.	R.E. Whitson[c]	1993-present

[a]Name changed in 1965

[b]Name changed in 1991

[c]RLEM and Agricultural Economics faculty, 1974-1981

A 50-year anniversary dinner took place the evening of April 27, 1996, to celebrate 50 years of rangeland education and research for the people of Texas and the nation.

Assessment of Weed and Brush Research Needs

Weeds and brush are serious barriers to economic livestock production, wildlife habitat, watershed yield, recreation, and aesthetics on many rangeland sites. Much of the problem is due to man's activities and economic pursuits. However, the problem grows larger each year and cannot be solved without man's interference and sound management. Noxious weeds and brush are dominating much of the western U.S. and control efforts need intense political and public support or the land will become nearly useless and costly to restore.

Weed and brush management is part of the restoration scheme and all present and future forms of herbicides, prescribed burning, mechanical, and biological control methods will be required to deal with the problem, either alone or in some possible combination (integrated weed management systems or integrated brush management systems).

Mechanical methods of weed control are the most common on rangelands, including handgrubbing, mowing, or bulldozing. These practices have been developed by man's necessity to control weeds and brush. Although there is a lot of handheld and power equipment for weed and brush control (216), there are always ways to improve current technology as demonstrated by Weidemann et al. (221, 222, 223). Mechanical methods will continue to be an important means to control brush and weeds on rangelands alone and in combination with other methods.

Herbicides have limitations on rangelands because of cost; however, on selected sites herbicides will continue to be very useful. On certain sites they are the only means possible. Herbicides have unjustly received bad press (41, 42), limiting their use and increasing the cost of application. Harris and Reid (152) indicated herbicides are useful in California to economically control exotic plants that destroy native habitats on which many endangered species depend.

Even though herbicide use on rangelands may be very infrequent (every 20 years) compared to cropland, future use will be further reduced and delivery systems will be more efficient, as in the individual plant treatments of Ueckert (213) on mesquite and pricklypear cactus and the herbicide carpeted roller (56, 163, 165). Aircraft can now apply small amounts of pelleted herbicides (36) and new developments in aerial sprays (38, 107, 146) improve spray deposit and reduce drift. Electronic sensors, monitors, and control systems on ground sprayers can spray only the target species with precison (24).

New generation herbicides such as the sulfonylurea and related compounds control weeds at extremely low rates (fraction of an ounce per acre). Other new developments will follow in finding new and improved chemistry, formulations, and delivery systems. Herbicide research in agronomic cropping systems has been well supported by private, state, and federal funding. Herbicide research for rangelands has been well supported in the past, but now funding is essentially non-existent.

Many argue that chemical companies can provide the necessary data for agriculture use without input from private, state, or federal research. Although the chemical companies provide very useful and timely data, much of it comes from state and federally supported research. Also the information required for environmental safety, minor crop use, and other details is sometimes too overwhelming for the company and they need help to expand opportunities of mutual interest.

Prescribed burning for weed and brush control will continue to be important in Texas especially in connection with other practices (213). Historically fire was a major natural event in controlling weeds and brush and renewing of grasslands. Prescribed burning has become more attractive because of high costs of other practices. It can definitely be beneficial in remote areas with enough fuel to carry the fire.

Biological control, especially with insects, is receiving a lot of attention in ARS and some state programs. Weed and brush management may also be enhanced by intensive short duration grazing systems in which deer, goats, and cattle can use woody and herbaceous plants more efficiently. Enough vegetative cover needs to be left to protect wildlife, but also be compatible with livestock use. Forthcoming research should develop best stocking ratios of livestock and wildlife. More creative use should be made of exotic game and goats.

Some success has been gained with insects and plant pathogens for control of weeds, but most programs have been unsuccessful. Control with insects and plant pathogens is highly expensive (until acceptable control is achieved), extremely slow,

uncertain, and risks escape of organisms that may feed on desirable vegetation. Even though these bio-control organisms are an environmental risk, they may be the only means to suppress vast acreages of range weeds in the U.S. and further work should be encouraged.

One area needing renewed and increased effort is in revegetation of pastures and rangeland. Research work in the past has been poorly supported and sporadic. This involves investigation of native and introduced plant species for establishment and maintenance of stands under grazing use. Weed control is usually necessary for seedling establishment and can be accomplished by herbicides, mowing, or cultivation. Use of forage crops with allelopathic properties to suppress weeds should be studied. Ecological restoration of rangelands is high priority research and should be given considerable attention and support.

Further research on integrated weed and brush management systems should be given high priority, looking at all possible combinations of mechanical, chemical, fire, biological, and plant competition/allelopathy/revegetation to fit the site, cost, and purposes of the land manager. Combinations of treatments are selected on the basis of availability, weed species, cost, effectiveness, and other factors. Computer decision-making programs such as EXSEL (151) will be continually improved as data input and technology dictate.

Finally, to know the life cycles, ecology, physical and physiological characteristics, environmental responses, and growth characteristics of each weed and brush species we are dealing with is essential to understanding their nature of encroachment and persistence on rangelands. Dr. R.E. Meyer (ARS) and coworkers attempted to obtain such information through numerous investigations, including his classical work on the anatomy and morphology of honey mesquite and other weeds and brush (164, 172, 183, 184, 185, 190, 232).

This kind of research was not encouraged in the 1960s or 1970s by ARS or by the TAES. However, at the 1982 ARS Research Planning Conference (2) in College Station, Texas, "Study of the biology, ecology, and edaphic factors as the basis for control technology" was given first priority. Dr. Meyer and co-workers continued to work in this area of research until he retired in 1988. Dr. Meyer worked on the anatomy, morphology, and biology of western ragweed, yankeeweed, woolly croton, and bitter sneezeweed, as well as control of these species.

The ARS group at Temple, Texas (162) is working in this area as is TAES (5, 6, 96, 97, 198). It is essential that work on the ecology, biology, and ecophysiology be continued if progress in weed and brush management is to be made.

Literature Cited

1. Anonymous. 1972. Symposium Commemorating 25 years. Teaching-Research-Extension, Range Science Dept., Texas A&M University, Texas A&M Press, College Station, TX. 65p.
2. Anonymous. 1982. Report of the ARS planning conference on weed and brush control and related integrated research on rangelands. USDA, ARS. College Station, TX. 34p.
3. Ansley, J.R. 1991. Brush management and water. pp. 23-30. in T.G. Welch, (ed). Proc. Brush Manage. Sym.. Texas Agric. Ext. Serv. Abilene, TX.
4. Ansley, R.J., P.W. Jacoby, and R.A. Hicks. 1991. Leaf and whole plant transpiration in honey mesquite following severing of lateral roots. J. Range Manage. 44:577-582.
5. Archer, S. 1993. Vegetation dynamics in changing environments. Rangel. J. 15:104-116.
6. Archer, S. 1995. Mechanisms of shrubland expansion: land use, climate or CO_2? Climate Change 29:91-99.
7. Baur, J.R., and J.J. Bowman. 1972. Effect of 4-amino-3,5,6-trichloropicolinic acid on protein synthesis. Physiol. Plant. 27:354-359.
8. Baur, J.R., and J.J. Bowman. 1973. Subcellular distribution of picloram. Physiol. Plant. 28:372-373.
9. Baur, J.R., and P.W. Morgan. 1969. Effects of picloram and ethylene on leaf movement in huisache and mesquite seedlings. Plant Physiol. 44:831-838.
10. Baur, J.R. and R.W. Bovey. 1969. Distribution of root-absorbed picloram. Weed Sci. 17:524-528.
11. Baur, J.R., and R.W. Bovey. 1970. The uptake of 4-amino-3,5,6-tricholoropicolinic acid (picloram) by potato tuber tissue. Weed Sci. 18:22-24.
12. Baur, J.R., and R.W. Bovey. 1974. Ultraviolet and volatility loss of herbicides. Arch. Environ. Contam. Toxicol. 2:275-288.
13. Baur, J.R., and R.W. Bovey. 1975. Herbicidal effects of tebuthiuron and glyphosate. Agron. J. 67:547-553.
14. Baur, J.R., R.D. Baker, R.W. Bovey, and J.D. Smith. 1972. Concentration of picloram in the soil profile. Weed Sci. 20:305-309.
15. Baur, J.R., R.D. Baker, R.W. Bovey, J.D. Smith, and M.G. Merkle. 1972. Concentration of picloram in runoff water. Weed Sci. 20:309-313.
16. Baur, J.R., R.W. Bovey, and C.R. Benedict. 1970. Effect of picloram on growth and protein levels in herbaceous plants. Agron. J. 62:627-630.
17. Baur, J.R., R.W. Bovey, and H.G. McCall. 1973. Thermal and ultraviolet loss of herbicides. Arch. Environ. Contam. Toxicol. 1:289-302.
18. Baur, J.R., R.W. Bovey, and J.D. Smith. 1972. Effect of DMSO and surfactant combinations on tissue concentrations of picloram. Weed Sci. 20:298-302.
19. Baur, J.R., R.W. Bovey, P.S. Baur, and Z. El-Seify. 1969. Effect of paraquat on the ultrastructure of mesquite mesophyll cells. Weed Res. 9:81-85.
20. Baur, J.R., R.W. Bovey, R.E Meyer, T.O. Flynt, and T.E. Riley. 1972. Efficiency of a tractor-mounted field sprayer. Weed Sci. 20:317-319.
21. Behrens, R. 1957. Influence of various components on the effectiveness of 2,4,5-T sprays. Weeds 5:183-196.
22. Behrens, R., and H.L. Morton. 1963. Some factors influencing activity of 12 phenoxy acids on mesquite root inhibition. Plant Physiol. 38:165-170.
23. Behrens, R., W.C. Hall, and C.E. Fisher. 1955. Field responses of cotton to four phenoxy-type herbicides. Proc. South Weed Conf. 8:72-75.
24. Bode, L.E., and B.J. Butler,. 1983. New techniques and equipment for ground application of herbicides in the U.S.A. pp. 478-485. in Vol. 2, Proc. 10th Int. Congress of Plant Protection, Brighton England.
25. Bouse, L.F. 1969. Aerial spray penetration through foliage canopies Trans ASAE. 12:86-89.
26. Bouse, L.F. 1974. Properties of water jet stream sprays related to cycles disturbance. Trans. ASAE. 17:814-820.
27. Bouse, L.F. 1975. Use of pulsed jets to atomize various liquids Trans. ASAE. 18:618-622.
28. Bouse, L.F. 1976. Spray recovery from nozzle designed to reduce drift. Weed Sci. 24:361-365.
29. Bouse, L.F. 1994. Effect of nozzle type and operation on spray droplet size. Trans. ASAE. 37:1389-1400.
30. Bouse, L.F., and J.B. Carlton. 1985. Factors affecting size distribution of vegetable oil spray droplets. Trans. ASAE 28:1068-1073.
31. Bouse, L.F., and J.B. Carlton. 1985. Factors affecting distribution of herbicide pellets by aircraft. Trans. ASAE. 28:17-22 & 29.
32. Bouse, L.F., and M.G. Merkle. 1975. Comparison of recoveries from a tower-mounted dual sprayer. Trans ASAE. 18:467-470.
33. Bouse, L.F., and R.E. Leerskov. 1973. Drift comparisons of low-expansion foams and conventual sprays. Weed Sci. 21:405-409.
34. Bouse, L.F., D.G. Haile, and O.R. Kunze. 1974. Cyclic disturbance of jets to control spray drop size. Trans. ASAE. 17:235:239.
35. Bouse, L.F., I.W. Kirk, and L.E. Bode. 1990. Effect of spray mixture on droplet size. Trans. ASAE. 33:783-788.
36. Bouse, L.F., J.B. Carlton, and J.C. Brusse. 1982. Dry materials metering system for aircraft. Trans. ASAE. 25:316-320.
37. Bouse, L.F., J.B. Carlton, and P.C. Jank. 1988. Effect of water soluble polymers on spray droplet size. Trans. ASAE. 31:1633-1641.
38. Bouse, L.F., J.B. Carlton, I.W. Kirk, and T.J. Hirsch, Jr. 1994. Nozzle selection for optimizing deposition and minimizing spray drift for the AT-502 Air Tractor. Trans. ASAE. 37:1725-1731.
39. Bouse, L.F., S.G. Whisenant, and J.B. Carlton. 1992. Aerial spray deposition on mesquite. Trans. ASAE. 35:51-59.

40. Bovey, R.W. 1966. Recent advances in woody plant control in the Southwest. Agron. Absts. p. 105.

41. Bovey, R.W., and A.L. Young. 1980. Military uses of herbicides. pp. 371-403. in The Science of 2,4,5-T and Associated Phenoxy Herbicides. John Wiley & Sons. New York, NY.

42. Bovey, R.W. and A.L. Young. 1980. The Science of 2,4,5-T and Associated Phenoxy Herbicides. John Wiley & Sons, Inc., N.Y. 462p.

43. Bovey, R.W., and C.J. Scifres. 1971. Residual characteristics of picloram in grassland ecosystems. Tex. Agric. Exp. Stn. Bull. 1111. 24p.

44. Bovey, R.W., and C.W. Richardson. 1991. Dissipation of clopyralid and picloram in soil and seep flow in the Blacklands of Texas. J. Environ. Qual. 20:528-531.

45. Bovey, R.W., and H.S. Mayeux. 1980. Effectiveness and distribution of 2,4,5-T, triclopyr, picloram and 3,6-dichloropicolinic acid in honey mesquite (*Prosopis juliflora* var. *glandulosa*). Weed Sci. 28:666-670.

46. Bovey, R.W., and J.D. Diaz-Colon. 1977. Selected bibliography of the phenoxy herbicides. II. The substituted dibenzo-p-dioxins. Tex. Agric. Exp. Stn., MP-1323. 57p.

47. Bovey, R.W., and J.D. Diaz-Colon. 1978. Selected bibliography of the phenoxy herbicides. VIII. Effects on higher plants. Tex. Agric. Exp. Stn., MP-1388. 59p.

48. Bovey, R.W., and J.D. Diaz-Colon. 1978. Selected bibliography of the phenoxy herbicides. VI. Methods of extraction and analysis. Tex. Agric. Exp. Stn., MP-1381. 33p.

49. Bovey, R.W., and J.D. Diaz-Colon. 1978. Selected bibliography of the phenoxy herbicides. IV. Ecological effects. Tex. Agric. Exp. Stn., MP-1360. 28p.

50. Bovey, R.W., and J.R. Baur. 1972. Persistence of 2,4,5-T in grasslands of Texas. Bull. Environ. Contam. Toxicol. 8:229-233.

51. Bovey, R.W., and M.A. Hussey. 1991. Response of selected forage grasses to herbicides. Agron. J. 83:709-713.

52. Bovey, R.W., and P.W. Voigt. 1983. Tolerance of weeping lovegrass cultivars to herbicides. Crop Sci. 23:364-368.

53. Bovey, R.W., and R.E. Meyer. 1978. Control of huisache with soil applied herbicides. J. Range Manage. 31:179-182.

54. Bovey, R.W., and R.E. Meyer. 1983. Herbicide control methods-absorption and physiological considerations of the plant. pp. 45-52 in K. McDaniel (ed.). Brush Manage. Sym. Soc. Range Manage. Texas Tech. Press, Lubbock, TX.

55. Bovey, R.W., and R.E. Meyer. 1987. Influence of adjuvants and plant growth regulators on herbicide performance in honey mesquite. J. Plant Growth Regul. 5:225-234.

56. Bovey, R.W., and R.E. Meyer. 1989. Control of huisache and honey mesquite with a carpeted roller herbicide applicator. J. Range Manage. 42:407-411.

57. Bovey, R.W., and S.G. Whisenant. 1991. Control of honey mesquite with clopyralid, triclopyr or clopyralid:triclopyr mixtures. J. Range Manage. 44:52-55.

58. Bovey, R.W., and S.G. Whisenant. 1992. Honey mesquite (*Prosopis glandulosa*) control by synergistic action of clopyralid:triclopyr mixtures. Weed Sci. 40:563-567.

59. Bovey, R.W., and R.E. Meyer. 1985. Herbicide mixtures for control of honey mesquite (*Prosopis glandulosa*). Weed Sci. 33:349-352.

60. Bovey, R.W., E. Burnett, C. Richardson, J.R. Baur, M.G. Merkle, and D.E. Kissel. 1975. Occurrence of 2,4,5-T and picloram in subsurface water in the Blacklands of Texas. J. Environ. Qual. 4:103-106.

61. Bovey, R.W., E. Burnett, C. Richardson, M.G. Merkle, J.R. Baur, and W.G. Knisel. 1974. Occurrence of 2,4,5-T and picloram in surface runoff water in the Blacklands of Texas. J.Environ. Qual. 3:61-64.

62. Bovey, R.W., E. Burnett, C. Richardson, R.E. Meyer, and A. Loh. 1978. Persistence of tebuthiuron in surface runoff water, soil and vegetation in the Blacklands of Texas. J. Environ. Qual. 7:233-236.

63. Bovey, R.W., E. Franz, and S.G. Whisenant. 1994. Influence of organosilicone surfactants and spray nozzle types on the fate and efficacy of clopyralid in honey mesquite (*Prosopis glandulosa*). Weed Sci. 42:658-664.

64. Bovey, R.W., et al. 1982. The biologic and economic assessment of 2,4,5-T. USDA Tech. Bull. No. 1671. 445p.

65. Bovey, R.W., F.S. Davis, and H.L. Morton. 1968. Herbicide combinations for woody plant control. Weed Sci. 16:332-335.

66. Bovey, R.W., F.S. Davis, and M.G. Merkle. 1967. Distribution of picloram in huisache after foliar and soil applications. Weeds. 15:245-249.

67. Bovey, R.W., F.S. Davis, M.G. Merkle, R.E. Meyer, H.L. Morton, and L.F. Bouse. 1965. Defoliation and control of brush. Proc. South Weed Conf. 18:288-292.

68. Bovey, R.W., H. Hein, Jr., and F.N. Keeney. 1989. Phytotoxicity, absorption and translocation of five clopyralid formulations in honey mesquite (*Prosopis glandulosa*). Weed Sci. 37:19-22.

69. Bovey, R.W., H. Hein, Jr., and R.E. Meyer. 1984. Effect of herbicides on the production of common buffelgrass (*Cenchrus ciliaris* L.). Weed Sci. 32:8-12.

70. Bovey, R.W., H. Hein, Jr., and R.E. Meyer. 1986. Concentration of 2,4,5-T, triclopyr, picloram and clopyralid in honey mesquite (*Prosopis glandulosa*) stems. Weed Sci. 34:211-217.

71. Bovey, R.W., H. Hein, Jr., and R.E. Meyer. 1983. Absorption and translocation of triclopyr in honey mesquite (*Prosopis juliflora* var. *glandulosa*). Weed Sci. 31:807-812.

72. Bovey, R.W., H. Hein, Jr., and R.E. Meyer. 1988. Phytotoxicity and uptake of clopyralid in honey mesquite (*Prosopis glandulosa*) as affected by adjuvants and other herbicides. Weed Sci. 36:20-23.

73. Bovey, R.W., H. Hein, Jr., and R.E. Meyer. 1988. Mode of clopyralid uptake by honey mesquite (*Prosopis glandulosa*). Weed Sci. 36:269-272.

74. Bovey, R.W., H. Hein, Jr., F.N. Keeney, and S.G. Whisenant. 1990. Phytotoxicity and translocation of three clopyralid formulations in honey mesquite. J. Plant Growth Regul. 9:65-69.

75. Bovey, R.W., H. Hein, Jr., R.E. Meyer, and L.F. Bouse. 1987. Influence of adjuvants on the deposition, absorption and translocation of clopyralid in honey mesquite (*Prosopis glandulosa*). Weed Sci. 35:253-258.

76. Bovey, R.W., H.L. Morton, and J.R. Baur. 1969. Control of live oak by herbicides applied at various rates and dates. Weed Sci. 17:373-376.

77. Bovey, R.W., H.L. Morton, J.R. Baur, J.D. Diaz-Colon, C.C. Dowler, and S.K. Lehman. 1969. Granular herbicides for woody plant control. Weed Sci. 17:538-541.

78. Bovey, R.W., H.L. Morton, R.E. Meyer, T.O. Flynt, and T.E. Riley. 1972. Control of yaupon and associated species. Weed Sci. 20:246-249.

79. Bovey, R.W., J.R. Baur, and E.C. Bashaw. 1979. Tolerance of kleingrass to herbicides. J. Range Manage. 32:337-339.

80. Bovey, R.W., J.R. Baur, and H.L. Morton. 1969. Control of huisache and associated woody species in south Texas. J. Range Manage. 23:47-50.

81. Bovey, R.W., J.R. Baur, and J.D. Diaz-Colon. 1974. Phytotoxicity of 2,4,5-T, picloram and dicamba alone and in mixtures in tissue culture. Weed Sci. 22:191-192.

82. Bovey, R.W., J.R. Baur, M.G. Merkle, and E.C. Bashaw. 1980. Response of kleingrass and buffelgrass to herbicides. Agron. J. 72:53-55.

83. Bovey, R.W., M.L. Ketchersid, and M.G. Merkle. 1979. Distribution of triclopyr and picloram in huisache. Weed Sci. 27:527-531.

84. Bovey, R.W., M.L. Ketchersid, and M.G. Merkle. 1970. Comparison of salt and ester formulations of picloram. Weed Sci. 18:447-451.

85. Bovey, R.W., R.A. Stermer, and L.F. Bouse. 1991. Spray deposition of clopyralid on honey mesquite (*Prosopis glandulosa*). Weed Technol. 5:499-503.

86. Bovey, R.W., R.E. Meyer, and H. Hein, Jr. 1982. Soil persistence of tebuthiuron in the Claypan Resources Area of Texas. Weed Sci. 30:140-144.

87. Bovey, R.W., R.E. Meyer, and J.R. Baur. 1981. Potential herbicides for brush control. J. Range Manage. 32:144-148.

88. Bovey, R.W., R.E. Meyer, L.F. Bouse, and J.B. Carlton. 1985. Seasonal response of woody plants to tebuthiuron pellets. Weed Sci. 33:551-554.

89. Bovey, R.W., R.E. Meyer, M.G. Merkle, and E.C. Bashaw. 1986. Effect of herbicides and handweeding on establishment of kleingrass and buffelgrass. J. Range Manage. 39:547-551.

90. Bovey, R.W., R.E. Meyer, R.D. Baker, and J.R. Baur. 1972. Evaluation of polymerized herbicides for brush control. Weed Sci. 20:332-335.

91. Bovey, R.W., R.H. Haas, and R.E. Meyer. 1972. Daily and seasonal response of huisache and Macartney rose to herbicides. Weed Sci. 20:577-580.

92. Bovey, R.W., S.K. Lehman, H.L. Morton, and J.R. Baur. 1969. Control of live oak in south Texas. J. Range Manage. 22:315-318.

93. Bovey, R.W., T.O. Flynt, R.E. Meyer, J.R. Baur, and T.E. Riley. 1976. Subsurface herbicide applicator for brush control. J. Range Manage. 29:338-341.

94. Bovey, R.W., V.L. Hauser, and R.E. Meyer. 1990. Establishment of kleingrass with annual ryegrass and other cultural treatments. Agron. J. 82:216-221.

95. Box, T.W., and R.S. White. 1969. Fall and winter burning of south Texas brush ranges. J. Range. Manage. 22:373-376.

96. Brown, J.R., and S. Archer 1990. Water relations of a perennial grass and seedling versus adult woody plants in a subtropical savanna, Texas. Oikos. 57:366-374.

97. Brown, J.R., and S. Archer. 1989. Woody plant invasion of grasslands: establishment of mesquite (*Prosopis glandulosa*) on sites differing in herbaceous biomass and grazing history. Oecologia 80:19-26.

98. Carlson, D.H., T.L. Thurow, R.W. Knight, and R.K. Heitschmidt. 1990. Effect of honey mesquite on water balance of Texas Rolling Plains rangeland. J. Range Manage. 43:491-496.

99. Carlton, J.B. 1975. Electrical capacitance determination and some implications for an electrostatic spray-charging aircraft. Trans ASAE. 18:641-644.

100. Carlton, J.B. 1991. Aerial spray deposit analysis II. A spray displacement index. Trans. ASAE. 34:1985-1988.

101. Carlton, J.B., and L.F. Bouse 1977. Distribution of the electric-field for an electrostatic spray charging aircraft. Trans. ASAE. 20:248-257.

102. Carlton, J.B., and L.F. Bouse. 1978. Spray deposit sampling technique to evaluate electrostatic aerial spray-charging. Trans. ASAE. 21:2-5.

103. Carlton, J.B., and L.F. Bouse. 1980. Electrostatic spinner-nozzle for charging aerial sprays. Trans. ASAE. 23:1369-1378.

104. Carlton, J.B., and L.F. Bouse. 1981. Characterizing spray deposit on film by light transmission. Trans. ASAE. 24:277-280.

105. Carlton, J.B., and L.F. Bouse. 1988. Exploring aerial spray sampling with a cylindrical collector. Trans. ASAE. 31:990-997.

106. Carlton, J.B., L.B. Bouse, J.A. Witz, and H.P. O'Neal. 1985. Automating aerial spray deposit analysis. Trans. ASAE. 28:1401-1405.

107. Carlton, J.B., L.F. Bouse, and I.W. Kirk. 1995. Electrostatic charging of aerial spray over cotton. Trans. ASAE. 38:1641-1645.

108. Carlton, J.B., L.F. Bouse, H.P. O'Neal, and W.J. Walla. 1981. Measuring spray coverage on soybean leaves. Trans. ASAE. 24:1108-1110.

109. Carlton, J.B., L.F. Bouse, H.P. O'Neal, W.J. Walla. 1983. Mechanical factors affecting aerial spray coverage of soybeans. Trans. ASAE. 26:1605-1607.

110. Carlton, J.B., L.F. Bouse, R.A. Stermer, and I.W. Kirk. 1990. Aerial spray deposit analysis I: Cylindrical collector drop size effects. Trans. ASAE. 33:1795-1800.

111. CAST. 1975. The Phenoxy Herbicides. Weed Sci. 23:253-263, and CAST Report No. 39.

112. Cuomo, C.J., R.J. Ansley, P.W. Jacoby, and R.E. Sosebee. 1992. Honey mesquite transpiration along a vertical site gradient. J. Range Manage. 45:334-338.

113. Darrow, R.A., and W.G. McCully. 1958. Pellet application of fenuron for the control of post and blackjack oaks. Texas Agric. Exp. Stn. Prog. Rept. 2041. 4p.

114. Darrow, R.A., and W.G. McCully. 1959. Brush control and range improvement in the post oak-blackjack oak area of Texas. Texas Agric. Exp. Stn. Bull. 942. 16p.

115. Darrow, R.A. Date unknown. Current status and trends in the development of woody plant control programs in Texas, Dept. Range & Forestry, Texas Agric. Exp. Stn. Mimeograph copy. 5p.

116. Davis, F.S., M.G. Merkle, and R.W. Bovey. 1968. Effect of moisture stress on the absorption and transport of herbicides in woody plants. Bot. Gaz. 1129:183-189.

117. Davis, F.S., R.W. Bovey, and M.G. Merkle. 1968. The role of light, concentration and species in foliar uptake of herbicides in woody plants. Forest Sci. 17:164-169.

118. Davis, F.S., R.W. Bovey, and M.G. Merkle. 1968. Effect of paraquat and 2,4,5-T on the uptake and transport of picloram in woody plants. Weed Sci. 16:336-339.

119. Day, B.E. 1978. The phenoxy herbicides. (2nd Ed.). Council for Agric. Sci. & Tech. (CAST) Report No. 77. 28p.

120. Diaz -Colon, J.D., and R.W. Bovey. 1978. Selected bibliography of the phenoxy herbicides. V. Interrelations with microorganisms. Tex. Agric. Exp. Stn., MP-1379. 87p.

121. Diaz-Colon, J.D., and R.W. Bovey. 1976. Selected bibliography of the phenoxy herbicides. I. Fate in the environment. Tex. Agric. Exp. Stn., MP-1303. 61p.

122. Diaz-Colon, J.D. and R.W. Bovey. 1977. Selected bibliography of the phenoxy herbicides. III. Toxicological studies in animals. Tex. Agric. Exp. Stn., MP-1343. 105p.

123. Diaz-Colon, J.D., and R.W. Bovey. 1978. Selected bibliography of the phenoxy herbicides. VII. Military uses. Tex. Agric. Exp. Stn., MP-1387. 25p.

124. Diaz-Colon, J.D., and R.W. Bovey. 1979. Selected bibliography of recent literature on the substituted dibenzo-p-dioxins. Tex. Agric. Exp. Stn., MP-1433. 50p.

125. Diaz-Colon, J.D., and R.W. Bovey. 1980. Selected bibliography of the phenoxy herbicides. IX. Toxicological and physiological effects of 2,4-D. Tex. Agric. Exp. Stn., MP-1454. 92p.

126. Diaz-Colon, J.D., R.W. Bovey, F.S. Davis, and J.R. Baur 1972. Comparative effects and concentration of picloram, 2,4,5-T and dicamba in tissue cultures. Physiol. Plant. 27:60-64.

127. Dodd. J.D. 1968. Mechanical control of pricklypear and other woody species on the Rio Grande Plains. J. Range Manage. 21:366-370.

128. Dodd, J.D., and S.T. Holtz. 1972. Integration of burning with mechanical manipulation of south Texas grassland. J. Range Manage. 25:130-135.

129. Dugas, W.A., M.L. Heuer, and H.S. Mayeux, Jr. 1992. Diurnal measurements of honey mesquite transpiration using stem flow gauges. J. Range Manage. 45:99-102.

130. Dugus, W.A., and H.S. Mayeux, Jr. 1991. Evaporation from rangeland with and without honey mesquite. J. Range Manage. 44:161-170.

131. Fisher, C.E., and D.E. Young, 1949. Cut-surface applications of herbicides to mesquite (*Prosopis juliflora*). North Central Weed Control Conf. Res. Rept. 6:147.

132. Fisher, C.E. and D.W. Young. 1948. Some factors influencing the penetration and mobility of chemicals in the mesquite plant. Proc. North Central Weed Control Conf. 6:197-202.

133. Fisher, C.E. and D.W. Young. 1949. Airplane application of herbicides to mesquite (*Prosopis juliflora*). North Central Weed Control Conf. Res. Rept. 6:148.

134. Fisher, C.E. and D.W. Young. 1949. Tip emersion studies on mesquite (Prosopis juliflora). Proc. North Central Weed Control Conf. 6:214-215.

135. Fisher, C.E. and D.W. Young. 1950. Control of mesquite with 2,4,5-T and other growth-regulator herbicides applied by airplane. North Central Weed Control Conf. Res. Rept. 7:237-238.

136. Fisher, C.E. and D.W. Young. 1950. The effect of herbicide droplet size on the control of mesquite when applied by airplane equipment. Proc. North Central Weed Control Conf. 7:84-86.

137. Fisher, C.E. and P.T. Marion. 1949. Effect of mesquite control on gains of yearling steers. North Central Weed Control Conf. Res. Rept 6:147.

138. Fisher, C.E., C.H. Meadors, and R. Behrens. 1956. Some factors that influence the effectiveness of 2,4,5-trichlorophenoxy acetic acid in killing mesquite. Weeds 4:139-147.

139. Fisher, C.E., C.H. Meadors, R. Behrens, E.D. Robison, P.T. Marion and H.L. Morton. 1959. Control of mesquite on grazing lands. Tex. Agric. Exp. Stn. Bull. 935. 24p.

140. Fisher, C.E., H.T. Wiedemann, J.P. Walter, C.H. Meadors, J.H. Brock, and B.T. Cross. 1972. Brush control research on rangeland. Texas Agric. Exp. Sta. MP-1043.18p.

141. Fisher, C.E., W.M. Phillips, C.H. Meadors, Jr., R.A. Darrow and W.G. McCully. 1952. Mesquite control. Cooperative ranch tests, 1950-51. Progress Rept. 1465, Tex. Agric. Exp. Stn. 10p.

142. Flynt, T.O, R.W. Bovey, R.E. Meyer, T.E. Riley, and J.R. Baur. 1976. Granular herbicide applicator for brush control. J. Range Manage. 29:435-437.

143. Franz, E. 1993. Machine vision using image gradients for spray-deposit analysis: software development. Trans. ASAE. 36:1955-1965.

144. Franz, E. 1993. On-board monitoring of ground speed and height-of-flight of agricultural aircraft. Trans. ASAE. 36:309-316.

145. Franz, E. 1993. Spray coverage analysis using a hand-held scanner. Trans. ASAE. 36:1271-1278.

146. Franz, E., J.B. Carlton, L.F. Bouse and I.W. Kirk. 1995. Within-canopy airflows and spray movement for fixed-wing aircraft. Trans. ASAE. 38:389-394.

147. Franz, E., M.R. Gebhardt and K.B. Unklesbay. 1995. Alogorithms for extracting leaf boundary information from digital images of plant foliage. Trans. ASAE. 38:625-633.

148. Garcia-Holguin, M., R.W. Bovey, and J.L. Schuster. 1991. Control of woody species in grazing lands on the Pacific Coast of Mexico. J. Range Manage. 44:508-512.

149. Gebhardt, M.R., C.L. Webber, III, and L.F. Bouse. 1985. Comparison of a rotary atomizer to a fan nozzle for herbicide application. Trans. ASAE. 28:382-385.

150. Hamilton, W.T. 1993. Past history and brush control in Texas. A personal perspective of efforts in South Texas. Presented at the Dallas Workshop on Brush Mgmt. in Texas. Texas Agric. Exp. Stn. 32p.

151. Hamilton, W.T., T.G. Welch, B.R. Myrick, B.G. Lyons, J.W. Stuth and J.R. Conner. 1993. EXSEL: expert system for brush and weed control technology selection. pp. 391-398. in C.D. Heatwole (ed.). Application of Advanced Information Technologies: Effective Management of Natural Resources. Proc. ASAE. Conf. 18-19 June 1993. Spokane, WA.

152. Harris, V. and T.S. Reid. 1994. Use of herbicides for endangered species protection. pp. 24-25. in Proc. California Weed Conf. San Jose, CA.

153. Heitschmidt, R.E., R.D. Schultz and C.J. Scifres, 1986. Herbaceous biomass dynamics and net primary production following chemical control of honey mesquite. J. Range Manage. 39:67-71.

154. Heitschmidt, R.K. and S.L. Dowhower. 1991. Herbage response following control of honey mesquite within single tree lysimeters. J. Range Manage. 44:144-149.

155. Hoffman, G.O, M.G. Merkle, and R.H. Haas. 1972. Controlling mesquite with Tordon 225 mixture herbicide in the Texas Blackland prairie. Down to Earth 27:pages unknown.

156. Jacoby, P.W. and C.H. Meadors. 1983. Triclopyr for control of honey mesquite (*Prosopis juliflora* var. *glandulosa*). Weed Sci. 31:681-685.

157. Jacoby, P.W., C.H. Meadors, and M.F. Foster. 1981. Control of honey mesquite (*Prosopis juliflora* var. *glandulosa*) with 3,6-dichloropicolinic acid. Weed Sci. 29:376-378.

158. Jacoby, P.W., C.H. Meadors, M.A. Foster and F.S. Hartmann. 1982. Honey mesquite control and forage response in Crane Country, Texas. J. Range Manage. 35:424-426.

159. Kirk, I.W., L.F. Bouse, J.B. Carlton, E. Franz, M.A. Latheef, J.E. Wright, and D.A. Wolfenbarger. 1994. Within-canopy spray distribution from fixed-wing aircraft. Trans. ASAE. 37:745-752.

160. Kirk, I.W., L.F. Bouse, J.B. Carlton, E. Franz and R.A. Stermer. 1992. Aerial spray deposition in cotton. Trans. ASAE. 35:1393-1399.

161. Knight, R.W. 1991. Water use of mesquite. Pages 8-11. Risks in ranching. PR-4872. Texas Agric. Exp. Stn. College Station, TX.

162. Mayeux, H.S., H.B. Johnson and H.W. Polley. 1991. Global change and vegetation dynamics. pp. 62-74. in L.F. James, J.D. Evans, M.H. Ralphs and R.D. Childs (eds.). Noxious Range Weeds. Westview Press, Boulder, CO.

163. Mayeux, H.S., Jr., and R.A. Crane. 1984. Application of herbicides on rangeland with a carpeted roller. Control of goldenweeds (*Iscoma* spp.) and false broomweed (*Ericamera austrotexana*). Weed Sci. 32:845-849.

164. Mayeux, J.S., Jr., C.J. Scifres, and R.E. Meyer. 1979. Some factors affecting the response of spring aster to herbicide sprays. Texas Agric. Exp. Sta., B-1197. 16p.

165. Mayeux, Jr., H.S., and R.W. Bovey. 1989. Response of huisache (*Acacia farnesiana*) seedings to herbicides applied with a model carpeted roller. Weed Technol. 3:232-237.

166. Mayeux, Jr., H.S., C.W. Richardson, R.W. Bovey, E. Burnett, M.G. Merkle, and R.E. Meyer. 1984. Dissipation of picloram in storm runoff. J. Environ. Qual. 13:44-49.

167. McBryde, G.L., J.R. Conner and C.J. Scifres. 1984. Economic analysis of selected brush management practices in Eastern South Texas. Texas Agric. Exp. Sta. B-1468. 13p.

168. Merkle, M.G. and F.S. Davis. 1967. Effect of moisture stress on absorption and movement of picloram and 2,4,5-T in beans. Weed. 15:10-13.

169. Merkle, M.G., R.E. Meyer, H.L. Morton, R.W. Bovey, and F.S. Davis. 1969. Brush control in east Texas timberlands. J. Range Manage. 23:129-132.

170. Merkle, M.G., R.W. Bovey, and F.S. Davis. 1967. Factors affecting the persistence of picloram in soil. Agron. J. 59:413-415.

171. Merkle, M.G., R.W. Bovey, and R. Hall. 1966. The Determination of picloram residues in soils using gas chromatography. Weeds. 14:161-164.

172. Meyer, R.E. 1974. Morphology and anatomy of Texas persimmon. Tex. Agric. Exp. Stn. B-1147-55p.

173. Meyer, R.E. and H.L. Morton. 1963. Factors affecting 2,4,5-T action on pricklypear. Proc. South Weed Conf. 16:401.

174. Meyer, R.E. and R.W. Bovey. 1973. Control of woody plants with herbicide mixtures. Weed Sci. 21:423-426.

175. Meyer, R.E. and R.W. Bovey. 1979. Control of honey mesquite (*Prosopis juliflora* var. *glandulosa*) and Macartney rose (R*osa bracteata*) with soil-applied herbicides. J. Range Manage. 32:3337-339.

176. Meyer, R.E. and R.W. Bovey. 1980. Control of live oak (*Quercus virginiana*) and understory vegetation with soil-applied herbicides. Weed Sci. 28:51-58.

177. Meyer, R.E. and R.W. Bovey. 1980. Control of whitebrush (*Aloysia lycioides*) and associated species with soil-applied herbicides. Weed Sci. 28:204-212.

178. Meyer, R.E. and R.W. Bovey. 1980. Hexazinone and other herbicides on Texas woody plants. Weed Sci. 28:358-362.

179. Meyer, R.E. and R.W. Bovey. 1984. Response of Macartney rose (*Rosa bracteata)* and understory vegetation to herbicides. Weed Sci. 32:63-67.

180. Meyer, R.E. and R.W. Bovey. 1985. Response of yaupon (*Ilex vomitoria*) and understory vegetation to herbicides. Weed Sci. 3:415-419.

181. Meyer, R.E. and R.W. Bovey. 1986. Influence of environment and stage of growth on honey mesquite (*Prosopis glandulosa*) response to herbicides. Weed Sci. 34:287-299.

182. Meyer, R.E. and R.W. Bovey. 1988. Tebuthiuron formulation and placement effects on response of woody plants and soil residue. Weed Sci. 36:373-378.

183. Meyer, R.E. and S.M. Meola. 1978. Morphological characteristics of leaves and stems of selected Texas woody plants. U.S. Dep. Agric., Agric. Res. Serv., Tech. Bull. No. 1564. 200p.

184. Meyer, R.E., H.L. Morton, R.H. Haas, and E.D. Robison. 1971. Morphology and anatomy of honey mesquite. USDA, ARS and Tex. Agric. Exp. Stn. Tech Bull. No. 1423. 186p.

185. Meyer, R.E., R.H. Haas and C.W. Wendt. 1973. Interaction of environmental variables on growth and development of honey mesquite. Bot. Gaz. 134:173-178.

186. Meyer, R.E., R.W. Bovey, and J.R. Baur. 1978. Control of an oak (*Quercus*) complex with herbicide granules. Weed Sci. 26:444-453.

187. Meyer, R.E., R.W. Bovey, L.F. Bouse, and J.B. Carlton. 1983. Response of live oak (*Quercus virginiana*) and understory vegetation to herbicides. Weed Sci. 31:639-547.

188. Meyer, R.E., R.W. Bovey, T.E. Riley, and T.O. Flynt. 1976. Seasonal response of Macartney rose and huisache to picloram. J. Range Manage. 29:157-159.

189. Meyer, R.E., R.W. Bovey, T.W. Riley, and W.T. McKelvy. 1972. Leaf removal interval effect after herbicide sprays to woody plants. Weed Sci. 20:498-501.

190. Meyer, R.E., R.W. Bovey, W.T. McKelvy, and T.E. Riley. 1972. Influence of plant growth stage and environmental factors on the response of honey mesquite to herbicides. Tex. Agric. Exp. Stn. B-1129.19p.

191. Meyer, R.E., T.E. Riley, H.L. Morton and M.G. Merkle. 1969. Control of whitebrush and associated species with herbicide in Texas. Tex. Agric. Exp. Stn. Bull. MP-930.18p.

192. Mitchel, R.D., L.F. Bouse, and L.E. Bode. 1990. Sampling techniques to determine droplet size spectrum for fan nozzles. Liquid particle size measurement techniques. ASTM STP 1083. pp. 238-245. in E.D. Hurleman, W.D. Bachalo and P.G. Felton, (eds.). Amer. Soc. for Testing Materials, Philadelphia, PA.

193. Morton, H.L. 1966. Influence of temperature and humidity on foliar absorption, translocation and metabolism of 2,4,5-T by mesquite seedlings. Weeds 14:136-141.

194. Morton, H.L. and R.E. Meyer. 1963. Absorption of substituted phenoxy acids by mesquite roots. Proc. South Weed Conf. 16:402.

195. Morton, H.L., E.D. Robison, and R.E. Meyer. 1967. Persistence of 2,4-D, 2,4,5-T and dicamba in range forage grasses. Weeds. 15:268-271.

196. Morton, H.L., F.S. Davis and M.G. Merkle. 1968. Radioisotopic and gas chromatographic methods for measuring absorption and translocation of 2,4,5-T by mesquite. Weed Sci. 16:88-91.

197. Mutz, J.L., C.J. Scifres, S. Selm, and R.F. Cook. 1978. Movement and persistence of karbutilate in rangeland soils. Weed Sci. 26:179-181.

198. Owen, M.K., R.B. Wallace and S. Archer. 1995. Seed dormancy and persistence of *Acacia berlandieri* and *Leucoena pulverulenta* in a semi-arid environment. J. Arid Environments. 29:15-23.

199. Richardson, C.W., E. Burnett, and R.W. Bovey. 1979. Hydrologic effects of brush control on rangelands. Transactions of the ASAE 22:315-319.

200. Robison, E.D. 1967. Response of mesquite to 2,4,5-T, picloram and 2,4,5-T/picloram combinations. Proc. South. Weed Conf. 20:199.

201. Scifres, C.J. and B.H. Koeth. 1989. Patterned herbicide applications. pp. 45-48. in Management of South Texas Mixed Brush with Herbicides. Texas Agric. Exp. Stn. B-1623.

202. Scifres, C.J. and G.O. Hoffman. 1972. Comparative susceptibility of honey mesquite to dicamba and 2,4,5-T. J. Range Manage. 25:143-146.

203. Scifres, C.J. and W.T. Hamilton. 1993. Prescribed Burning for Brushland Management. The South Texas Example. Texas A&M Univ. Press. College Station, TX. 246p.

204. Scifres, C.J., G.A. Rasmussen and R.P Smith. 1983. Integrated brush management system (IBMS) for rangeland: Concepts and potential technologies for running mesquite and whitebrush. Texas Agric. Exp. Stn. Bull. 1450. 13p.

205. Scifres, C.J., J.L. Mutz and C.H. Meadors. 1978. Response of range vegetation to grid placement and aerial application of karbutilate. Weed Sci. 26:139-144.

206. Scifres, C.J., J.W. Stuth, and R.W. Bovey. 1981. Control of oaks (*Quercus* spp.) and associated woody species on rangeland with tebuthiuron. Weed Sci. 29:270-275.

207. Scifres, C.J., W.T. Hamilton, J.M. Inglis and J.R. Conner. 1983. Development of integrated brush management systems (IBMS): decision-making processes. pp. 97-104. in K. McDaniel (ed.). Proc. Brush Manage. Sym. Soc. Range Manage. Texas Tech. Press, Lubbock, TX.

208. Scifres, C.J., W.T. Hamilton, J.R. Conner, J.M. Inglis, G.A. Rasmussen, R.P. Smith, J.W. Stuth, and T.G. Welch. 1985. Integrated brush management systems for south Texas: Development and Implementation. Texas Agric. Exp. Stn. B-1493. 69p.

209. Scifres, C.J.. 1980. Brush Management: Principles and Practices for Texas and the Southwest. Texas A&M Univ. Press. College Station, TX. 360p.

210. Swanson, C.R. 1979. Assessment of rangeland brush research in Oklahoma and Texas. USDA, ARS. 48p.

211. Swanson, C.R. and J.R. Baur. 1969. Absorption and penetration of picloram in potato tuber discs. Weed Sci. 17:311-314.

212. Ueckert, D.N. 1993. Success and failures in brush and weed control research. Presented at the Dallas Workshop on Brush Mgmt. in Texas. Texas Agric. Exp. Stn. 9p.

213. Ueckert, D.N. 1995. Personal Communication.

214. Ueckert, D.N., J.L. Petersen, R.L. Potter, J.D. Whipple and M.W. Wagner. 1988. Managing pricklypear with herbicides and fire. Sheep & Goat, Wool & Mohair. Texas Agric. Exp. Stn. Prog. Rept. 4570. pp 10-15.

215. Valco, T.D., L.F. Bouse, and W.A. LePori. 1990. Development and evaluation of agricultural aircraft chemical injection system. ASAE Paper No. AA 90-006, ASAE, Reno, NV.

216. Vallentine, J.F. 1983. Mechanical brush control methods. pp. 53-59. in K.C. McDaniel (ed.). Brush Manage. Sym. Soc. Range Mange. Texas Tech. Press, Lubbock, TX.

217. Warren, L.E., D.N. Ueckert, M. Shelton and A.D. Chamrad. 1984. Spanish goat diets on mixed-brush grassland in the South Texas Plains. J. Range Manage. 37:340-342.

218. Whisenant, S.G., L.F. Bouse, R.A. Crane, and R.W. Bovey. 1993. Droplet size and spray volume effects on clopyralid phytotoxicity to honey mesquite. J. Range Manage. 46:257-261.

219. Whitson, R.E. and C.J. Scifres. 1980. Economic comparisons of alternatives for improving honey mesquite-infested rangeland. Texas Agric. Exp. Stn. Bull. 1307. 185p.

220. Whitson, R.E., W.T. Hamilton, and C.J. Scifres. 1979. Techniques and considerations for economic analysis of brush control alternatives. Texas A&M Univ., Range Sci. Dep. Tech. Rept. 79-1.

221. Wiedemann, H.T. and B.T. Cross. 1981. Low-energy grubbing for control of junipers. J. Range Manage. 34:235-237.

222. Wiedemann, H.T. and B.T. Cross. 1984. Influence of pulling configuration on draft of disk-chains. Trans. ASAE. 28:79-82.

223. Wiedemann, H.T., B.T. Cross and C.E. Fisher. 1977. Low-energy grubber for controlling brush. Trans. ASAE. 20:210-213.

224. Womac, A.R., J.E. Mulrooney, and L.F. Bouse. 1993. Spray drift from high-velocity aircraft. Trans. ASAE. 36:341-347.

225. Wright, H.A. and A.W. Bailey. 1982. Fire Ecology. John Wiley and Sons, New York, NY. 501p.

226. Young, D.W. and C.E. Fisher. 1949. Basal application of herbicides to mesquite (*Prosopis juliflora*). North Central Weed Control Conf. Res. Rept. 6:147-148.

227. Young, D.W. and C.E. Fisher. 1949. Shield tests on mesquite (*Prosopis juliflora*). North Central Weed Control Conf. 6:214.

228. Young, D.W. and C.E. Fisher. 1949. Treatments to the foliage of mesquite (*Prosopis juliflora*) with group equipment. North Central Weed Control Conf. Res. Rept. 6:147.

229. Young, D.W. and C.E. Fisher. 1950. Chaparral control. North Central Weed Control Conf. Res. Rept 7:250.

230. Young, D.W. and C.E. Fisher. 1950. Some factors affecting translocation of herbicides in mesquite. North Central Weed Control Conf. Res. Rept. 7:278-279.

231. Young, D.W. and C.E. Fisher. 1950. Toxicity and translocation of herbicides in mesquite. Proc. North Central Weed Control Conf. 7:95-99.

232. Young, D.W. and C.E. Fisher. 1950. Treatments to mesquite with ground equipment. North Central Weed Control Conf. Res. Rept 7:249.

233. Young, V.A., F.R. Anderwald and W.C. McCully. 1948. Brush problems in Texas Ranges. Misc. Pub. 21. 19p.

234. Zalay, A.D., L.F. Bouse, J.B. Carlton, H.R. Crookshank, W.R. Eberle, R.E. Howle, and K.R. Shrider. 1980. Measurement of airborne spray with a laser doppler velocimeter. Trans. ASAE. 23:548-552.

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